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THE GEOLOGY

OF THE

SMALL ISLES OF INVERNESS-SHIRE

(RUM, CANNA, EIGG, MUCK, Etc.)

(SHEET 60, SCOTLAND.)

BY

ALFRED HARKER, M.A., F.R.S.;

WITH CONTRIBUTIONS BY

G. BARROW, F.G.S.

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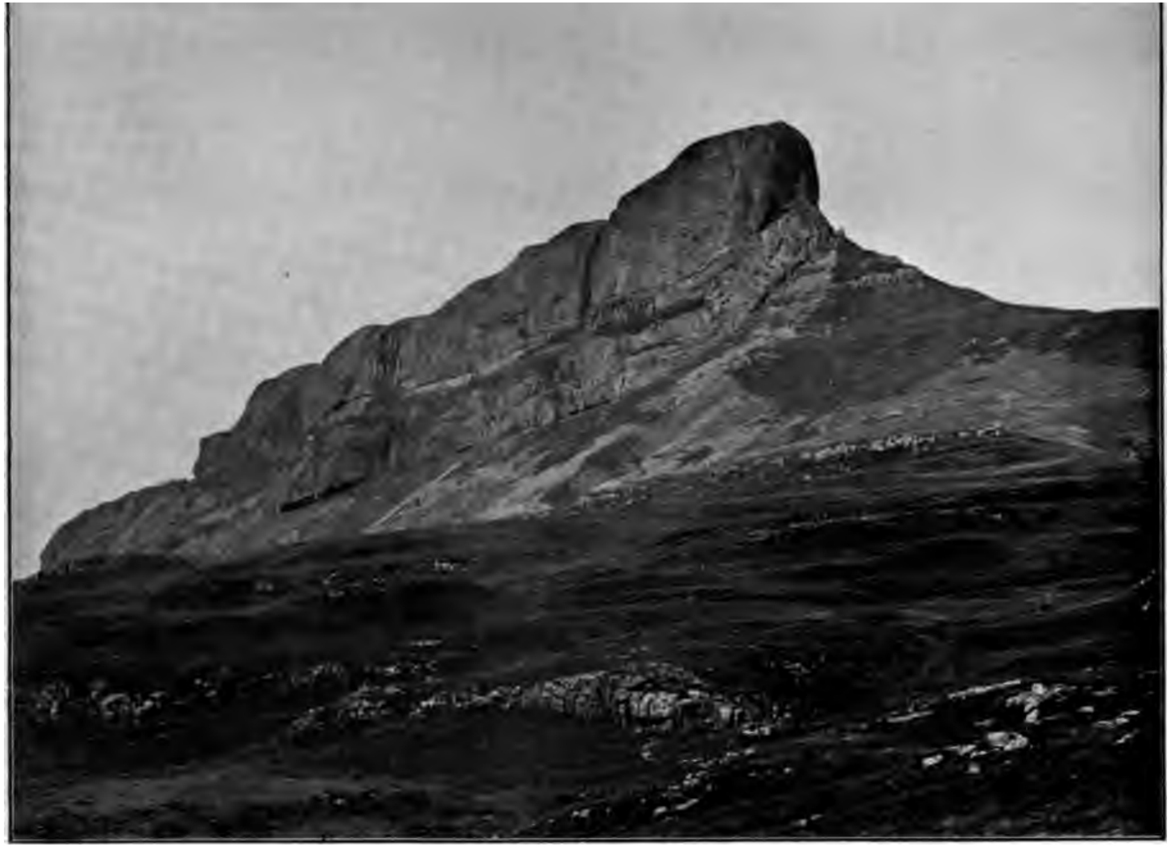

The Sgùrr of Eigg, seen from E.S.E., from near Galmisdale. Photograph by Mr. A. S. Reid.

The foreground is of basalt lavas with intrusive sills of dolerite, the latter making all the strong features. This succession extends to some height at the eastern end of the Sgùrr, where it is obliquely truncated by the pitchstone and its associated sheets of felsite. The precipitous ridge of the Sgùrr is made wholly

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PREFACE.

THE land area embraced in this sheet coincides with the parish of Small Isles, including Canna and Sanday, Rum, Eigg, Muck, and some smaller islands. The northern part of Eigg was surveyed in 1902 by Mr. Barrow and the remainder of the sheet in 1902-3 by Mr. Harker, excepting only the rocky islet Oigh-sgeir (or Hyskeir), for which notes have been furnished by Sir A. Geikie.

There is a considerable literature dealing with the geology of these islands (though principally with the one island of Eigg). Some notice of this will be found in Chapter I. and a full bibliography in an Appendix.

The present Memoir is written mainly by Mr. Harker, with contributions by Mr. Barrow dealing with the area surveyed by him. The principal points of interest brought out by the survey are, summarily:—

1. The recognition of the fact that the belt of Mid-Palæozoic overthrusting, already traced from Western Sutherland and Ross through the south-east part of Skye, is prolonged into Rum.
2. The discovery by D. Tait, fossil-collector, of scanty relics proving the presence of Cretaceous rocks in Eigg.
3. A more complete correlation of the Tertiary igneous succession in this area with that in Skye and other parts of the British province.
4. A full description of the very interesting group of ultrabasic rocks in Rum, of which Professor Judd had already given a preliminary account.
5. A study of the origin of a group of gneisses by the admixture of basic and acid plutonic rocks, with contemporaneous crust-movement, these Tertiary gneisses of Rum resembling in many particulars the Lewisian group,
6. A revision of the geology of the Sgùrr of Eigg, of which a first sketch was given many years ago by Sir A. Geikie.

A complete account of the Tertiary igneous rocks of this area would have been in great part a repetition of what has already been written of Skye. Accordingly the space has been devoted especially to those features of which the Small Isles afford the most characteristic development.

Eleven complete analyses of rocks and six partial analyses have been made by Dr. Pollard for this Memoir.

Professor Seward has kindly examined specimens of fossil wood from Eigg.

Three of the photographs reproduced in this Memoir have been kindly supplied by Mr. A. S. Reid and two by Mr. A. G. Stenhouse.

Three of the text-figures (15. 48. and 49) have appeared in the *Quarterly Journal of the Geological Society*. and we are indebted to the Council of the Society for permission to take *clichés* from the blocks.

During the progress of the survey every assistance was given by the proprietors of the several islands—Mr. R. L. Thomson of Eigg and Muck, Sir George Bullough of Rum, and Messrs. R. Thom, proprietor, and A. G. Thom, occupier, of Canna. Without the kind help and hospitality of these gentlemen the work would have been much more arduous and prolonged.

J. J. H. TEALL,
Director.

Geological Survey Office.
28 Jermyn Street, London.
9th November 1907.

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THE GEOLOGY

OF THE

SMALL ISLES OF INVERNESS-SHIRE

(RUM, CANNA, EIGG, MUCK, ETC.)

CHAPTER I.

INTRODUCTION.

(i.) GENERAL PHYSICAL FEATURES.

Sheet 60 of the map of Scotland covers an area occupied chiefly by the sea, but embracing* the several islands which make up the scattered parish of Small Isles.† The islands included are, in order of magnitude, Rum, Eigg with Castle Island (Eilean Chasgaidh), Canna with Sanday, Muck with Horse Island (Eilean nan Each), and Oigh-sgeir, besides some rocky islets of little note. The total land-area is only about 60 square miles. Rum, which is much the largest of the group, occupies a central position; Eigg lying four miles to the south-east, Sanday and Canna two and 3½ miles to the north-west, Muck six miles to the south, and Oigh-sgeir 10 miles to the west.

Rum has an area of nearly 42 square miles, and is of roughly quadrilateral outline. It divides, on the broadest view, into a northern moorland tract composed of Torridon sandstone, and a southern mountain tract composed of Tertiary plutonic rocks. The former rises to heights of nearly 1000 feet; the latter has a greater average elevation, and, though the highest point is only 2659 feet above the sea, the bold relief throughout this part of the island gives it the character of true mountain country. The Isle of Rum is principally devoted to sport; there is very little arable land, and most of the island is deer-forest, though sheep are also raised. Only a very small area is under cultivation.

---

* A small part of Canna falls into Sheet 70 and a narrow strip of Eigg into Sheet 61; but, by extending the map slightly beyond its strict boundaries, these portions are shown on the present sheet. The land-area of Sheet 60 as thus extended coincides with the parish of Small Isles.

† Before the Local Government (Scotland) Act, 1889, only Eigg, with Castle Island, belonged to the county of Inverness, the other isles being attached to Argyllshire. The whole parish is now included in the former county, but the older division is retained in the arrangement and numbering of the six-inch maps of the Ordnance Survey.

Eigg, with an area of about 12 square miles, is the chief centre of population, and contains the parish church. A depression extending from Laig Bay to Kildonan divides the higher ground to the north-east from that to the south-west. The north-eastern division is occupied inland by a hilly plateau, formed of Tertiary igneous rocks and rising to 1000 feet or more, while a belt of Jurassic strata follows the coast. In the south-western part of the island these older strata have sunk below sea-level, and the "basalt-plateau" type of scenery prevails. The highest ground, however, is made by the pitchstone ridge of Sgùrr of Eigg, rising to 1289 feet altitude, and extending in a sinuous course with a general north-west direction to the sea, a distance of about two miles. Eigg includes three small farms (now worked as one) and a crofter village, the rest of the island being under sheep and cattle.

Canna (4½ square miles) and Sanday (nearly one square mile) make practically a single island, being all but united at low tide. They exemplify again the plateau type of scenery characteristic of the Tertiary basaltic region. Canna rises to 690 feet, and has precipitous cliffs on its northerly side. The western end of the island is divided from the rest by a depression at Tarbert, and at the epoch of the 100-foot beach must have been detached. The greatest elevation of Sanday is only 193 feet. Here is a crofter township; but the remainder of the two islands is sheep-farm, with some arable land on the lower ground.

Muck (or Muke), though of similar constitution to Canna and the greater part of Eigg, is lower and flatter. With an area of 2½ square miles, it rarely rises 200 feet above the sea-level, the greatest elevation being 450 feet. Horse Island is joined to it at low water. Muck includes a larger proportion of cultivated land than is usual in the Inner Hebrides, besides excellent pasture, which supports a dairy-farm.

Oigh-sgeir (often spelt Hyskeir), an outlying dependency of Canna, is a group of rocky islets and reefs, rising only 34 feet above the Ordnance datum-line and having an area of about an eighth of a square mile. Before the recent erection of a lighthouse it has been uninhabited, and known only as the resort of seals and sea-birds.

(ii.) HISTORICAL.

If we except a few records of columnar basalts by Pennant and others, and some observations on pitchstones by Jameson, the first name demanding notice is that of John Macculloch, who may be said to have laid the foundation of all our knowledge of the geology of these islands (1819). Macculloch recognised the identity of the red (Torridonian) sandstone of Rum with that of Skye and the mainland, though the true age of this formation was a discovery of much later date. He also gave some account of the Secondary strata of Eigg and Muck, and identified them correctly with the upper part of the series of Trotternish in Skye. To the geologist of ninety years ago the complicated assemblage of igneous rocks here met with presented great difficulties. Macculloch, however, decided that they were "evidently posterior to some or all of the Secondary strata." The sheets intercalated in the sandstones and shales of Skye he had already proved to be intrusive sills, and he inclined to the same conclusion as regards Eigg, though he found the direct evidence less clear. The prevalent "trap" rocks of the islands (dolerite and basalt) are described by Macculloch in the language of his day, and his accounts of the Sgùrr of Eigg, the conglomerates of Canna, and other particular features of the district give evidence of close and acute observation. The remarkable crystalline rocks of the Rum mountains proved more puzzling. Macculloch's name "augit rock" for that which builds Allival and Askival was based on error, since it includes various peridotites and anorthite-olivine-rocks; nor did he appreciate the true relation of these rocks to the extensive area of peridotites ("with the aspect of rusty iron") which extends westward. He distinguished, however, the "syenite" (granite and granophyre) of the west coast of the island.

The contributions to the geology of the Small Isles made during the succeeding sixty-five years relate almost exclusively to the Isle of Eigg. Accounts of this island were published by von Oeynhausen and von Dechen, by Hay Cunningham, and by Hugh Miller, without adding much of importance to Macculloch's description. Then, in 1871, Sir Archibald Geikie published a paper in which he developed his view that the pitchstone forming the Sgùrr of Eigg represents a lava-flow filling an old valley excavated in the basalts. About this time, too, Professor Judd began his researches in the western isles of Scotland. His earlier work in this region was on the Secondary strata, and, in a paper published in 1878, he for the first time made a complete correlation, on palæontological evidence, of the Oolitic deposits of Eigg and Muck. Meanwhile he had been led to study the Tertiary igneous rocks, and had put forward in 1874 a paper dealing with this subject. The whole assemblage of rocks was considered to be connected with a number of large volcanoes, one of which was placed in Rum. Of subsequent contributions by the same geologist, the most important in relation to the Small Isles is one giving petrographical details of the interesting peridotites of the Rum mountains.

In 1888 Sir Archibald Geikie produced a memoir dealing generally with Tertiary igneous action in Britain, and recording numerous new facts. Rejecting the hypothesis of great isolated volcanoes, he urged rather a comparison with the lava-fields of Idaho, fed by fissure-eruptions. Among other observations, he noticed the evidence of over-thrusting in the Torridonian rocks of Rum and recognised the occurrence of gneiss, which he assigned to an Archæan age. He described also the remarkable stratified felspar-olivine-rocks of Allival and Askival, but, like Professor Judd, did not separate these and the other ultrabasic types from the gabbros. In a later paper (1896) Sir Archibald Geikie gave a full account of the volcanic agglomerate and fluviatile conglomerates of Canna and Sanday; and his work "The Ancient Volcanoes of Great Britain," besides embodying the results of his various earlier researches, contains new matter relating to the Small Isles in common with the rest of the Tertiary igneous region.

(iii.) TABLE OF FORMATIONS.

Post-Glacial,			Alluvium and Peat; Modern Beaches and Blown Sand. Raised Beaches.
Glacial,			Boulder-Clay and Erratics.
Pre-Glacial,			Sands of Laig Farm (Eigg).
Tertiary Igneous Rocks.			Minor intrusions (sills, dykes, &c.). Plutonic intrusions (in Rum and Muck). Volcanic rocks: basaltic lavas, with tuffs, river-conglomerates, &c.
Cretaceous.	Upper Greensand.		Calcareous Sandstone of Clach Alasdair (Eigg), with glauconitic sandy mud at base.
Jurassic,	Middle Oolites.	Upper Oxfordian.	(*b*) Shales. (*a*) Limestone and Sandstone.
	Lower Oolites.	Great Estuarine Series.	(*d*) Upper Shales. (*c*) Limestone. (*b*) Great Estuarine Sandstone. (*a*) Lower Shales.
Torridonian (Rum),			Sandstone group. Shale group.

CHAPTER II.

Torridonian System (Rum).

(i.) THE UNDISTURBED SEQUENCE.

In this sheet of the map Torridonian strata are seen only on the Isle of Rum. What is known of the broad structure of the Inner Hebrides leads us to suppose that these rocks underlie the whole of this group of islands, and this supposition is confirmed by the occurrence in the volcanic agglomerates and conglomerates of Canna and Eigg of blocks of red Torridon sandstone, probably derived, at least in the main, from some near subterranean source. Except in Rum, these ancient strata are everywhere below sea-level. In the northern parts of this island the sandstone forms hills 1000 feet high, and in the south-eastern part metamorphosed representatives of the Torridonian strata are found associated with the Tertiary plutonic rocks up to altitudes of nearly 2000 feet. The volcanic rocks of Tertiary age, which doubtless once overspread Rum, are now represented only by some inconsiderable outliers at elevations of 600 to 1000 feet. These facts point to a relative upheaval in Tertiary times in the neighbourhood of the plutonic focus of Rum. We shall see in the sequel that this movement, which has brought the Torridonian rocks here into prominence, was initiated at an early epoch, and probably renewed more than once. Indeed, the absence here of the Mesozoic strata, which underlie the Tertiary basalts on Eigg and Muck, is in itself sufficient to suggest such a repetition of local crust-movements.

Torridonian rocks play an important part in the geology of Rum; occupying most of the northern half of the island, and extending as a strip a half to three-quarters of a mile broad along the eastern, south-eastern, and southern coast nearly as far as Papadil. In addition to this continuous tract, which partly surrounds the principal mountains, there are smaller detached areas at higher altitudes, involved in the complex of plutonic rocks which builds the mountains themselves. Of the Torridonian strata thus distributed, part are in what may be regarded as their normal position, while part have been displaced by overthrusting connected with the great Mid-Palæozoic system of crust-movements. The overthrust rocks, intensely crushed, differ considerably in general appearance from their equivalents in the relatively undisturbed tract; and, being invaded in most places by the Tertiary plutonic intrusions, they are usually further disguised by the effects of thermal metamorphism.

The unmoved, or relatively unmoved, strata will be first described. They may be divided into two groups, as follows:—

(2) Upper, Sandstone Group, 9000 feet seen.
(1) Lower, Shale Group, 1400 feet seen.

A precise correlation with the succession in other parts of Scotland is not easily made; but doubtless some portion of the sandstones must be the equivalent of Mr. Clough's Applecross Grit, and the presence of shaly beds below is also in accord with what is seen in Skye and Ross-shire. The strata have the general north-westerly dip so prevalent in this region, the inclination being at moderate angles, often about 20°.

The shales,* in their undisturbed position, occupy a strip along the east coast from Bagh na h-Uamha (Cave Bay) to near Dibidil, and also reappear in the cliffs in the extreme south of the island, always passing regularly under the sandstone group. They are more or less indurated, but always have a marked lamination, often emphasised by alternations of lighter and darker films. Closer examination detects widespread irregularities on a small scale, the individual laminæ being broken by minute overthrusts or bent into acute zigzag folds. Occasional beds of sandstone are intercalated among the shales, and become frequent in the upper part of the group. It is a fine-grained quartzose sandstone of light-grey colour, and often has a pronounced lamination.

The upper or sandstone group has a much wider distribution, overlying the shales and forming, except for later igneous rocks, all the northern part of the island. It consists essentially of a monotonous succession of thick-bedded sandstones of varying texture. Coarser and finer beds alternate through a great part of the group, though the finer texture prevails in the lower portion. Many of the coarser beds contain abundant small pebbles, up to an inch or more in diameter. The sandstones in general contain a considerable amount of fresh felspar, largely pink microcline; and the rocks accordingly have a prevalent reddish colour, which is rarely wanting except where they have been bleached by subsequent metamorphism. There are occasional thin seams of dark colour, rich in magnetite and other heavy minerals. At a few horizons the finer-grained rocks assume a flaggy, or even a shaley, character, but this is not common. Notwithstanding the general appearance of great regularity and steady dips at moderate angles, this upper group, like the lower, shows on closer scrutiny widespread indications of mechanical disturbance on a small scale. On exposed summits, and especially in the coast-sections, the weathered faces of sandstone often exhibit violent contortions in beds which are divided by regular parallel bedding-planes. The interpretation of these structures is somewhat obscure, and it is doubtful whether they imply any important qualification of estimates of thickness based on measured sections. It may be noted, however, that the sandstones are occasionally brecciated, apart from the highly disturbed tracts to be more particularly described.

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* Macculloch remarked the shales, but identified them erroneously with [illegible] [Liassic] shales of Loch Eishort, in Skye. (*Descr. West. Is. Scot.*, vol. i., [illegible]81 : 1819.)

(ii.) THE OVERTHRUST ROCKS.

The overthrust Torridonian strata occur as a belt along the border of the mountains and also in a small separate area in the north-west of the island (fig. 1). The larger tract will be first described. Beginning to the north-east of Loch Sgathaig, known as the Long Loch, near the centre of the island, the outcrop of the main surface of discontinuity may be followed along a sometimes sinuous line, first eastward, then south-eastward across Coire Dubh; southward along the lower slopes of Allival and Askival;

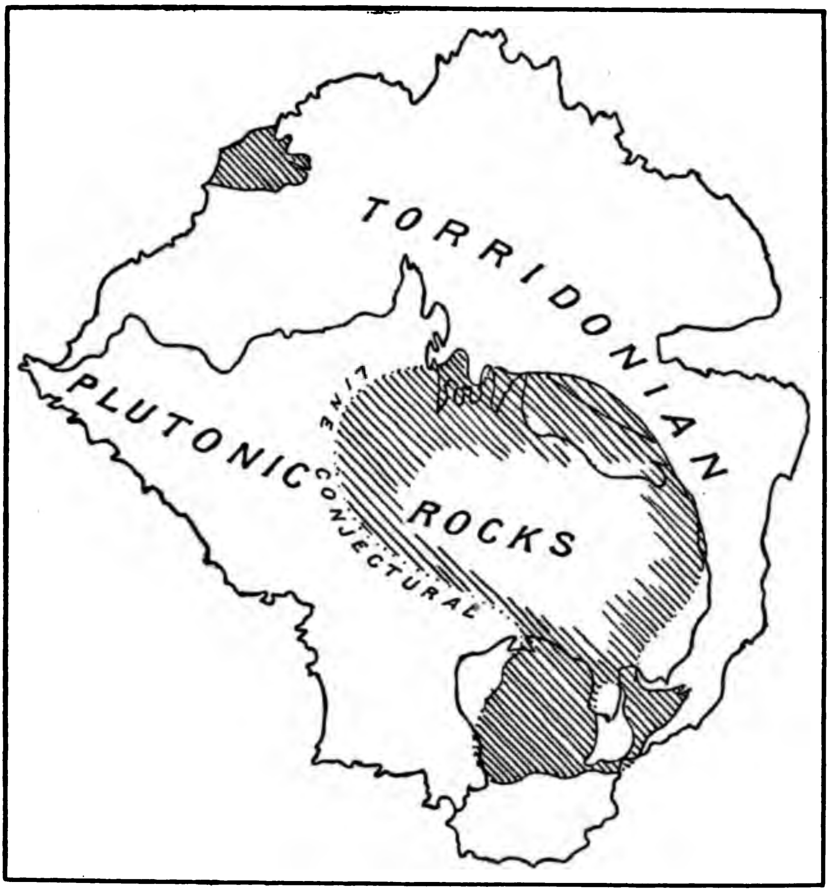


FIG. 1.—Sketch-Map of Isle of Rum to show the areas of overthrust Torridonian rocks (shaded).

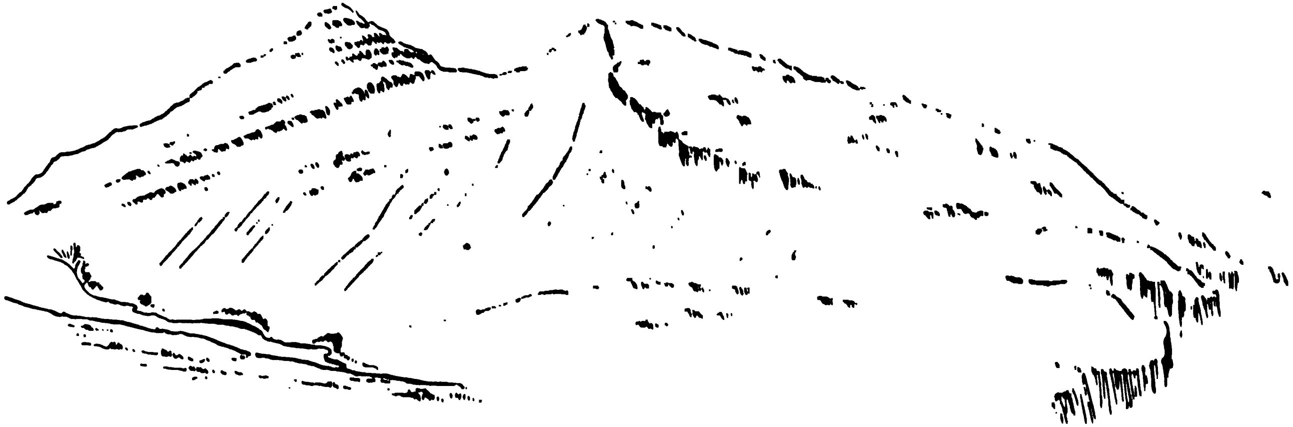


FIG. 2.—Outlines of Askival and Beinn nan Stac, seen from the south, across Glen Dibidil, Isle of Rum.

The seaward face of Beinn nan Stac, to the right, is made by a cake of overthrust and violently contorted shales resting on the (younger) sandstones, the surface of overthrust being marked by an escarpment. The craggy upper part of Beinn nan Stac is of a porphyritic quartz-felsite, described later. The dip between the two hills is made by eucrite, which comes down into Glen Dibidil. Askival, to the left, is built of the peridotite allivalite group, with strongly marked stratiform arrangement.

south-westward, with an intricate course in detail, to Dibidil; and thence westward to within three-eighths of a mile of Papadil. In parts of this generally semicircular course the line is interrupted by Tertiary plutonic intrusions, and westward the intrusive rocks occupy the whole of the ground, except that patches of the overthrust rocks are involved in them up to high altitudes on the western slopes of Ashval and Sgùrr nan Gillean. Prolonging the line in imagination, we have an area some 4¼ miles in diameter, including the principal mountain tract of Rum, within which the Torridonian strata have been overthrust. The greater part of this area is occupied by Tertiary plutonic rocks, leaving the overthrust Torridonian as a belt of varying width along the eastern half of the border, with some isolated patches in the midst of the intrusions.

The surface of overthrust is by no means a plane one. On the broadest view, it has a general inclination to south-east, coming down to sea-level at Dibidil. It is in this neighbourhood that the departure from a regular inclined plane is most marked. The area of overthrust rocks which forms the seaward face of Beinn nan Stac is practically an isolated outlier, the surface of displacement here having a general southerly dip, with strong undulations. (See sketch, fig. 2, and section, fig. 5.) It rises to at least 1500 feet towards the summit, but only 600 yards to the west, in Glen Dibidil, overthrust rocks are seen down to 600 feet altitude. On the southern slope of Sgùrr nan Gillean, again, the surface of overthrust reaches an elevation of nearly 1200 feet, declining sharply both eastward and westward. (See sketch, fig. 3.) On the northern and eastern sides of the mountains the surface outcrops usually at altitudes of 700 to 900 feet, but sinks to 400 in crossing the valley of Coire Dubh. In this part of the belt the inclination of the thrust-surface seems to be generally inward, towards the centre of the circle.

In general the overthrusting has taken effect along a single surface of displacement, or a single belt, but in one or two places there are "minor thrusts" beneath or in advance of it (fig. 4). The direction of movement indicated is apparently from south-east to north-west, which agrees approximately with the crust-movements presumably of the same system in other parts of the north-west Highlands. Rum lies nearly on the line of the great "Moine thrust," as prolonged from western Sutherland through the Sleat district of Skye; but the distance is too great to permit of our indentifying the main surface of displacement in our area with any one of the individual "thrust-planes" recognised elsewhere. Since the only ancient rocks represented in Rum are those of Torridonian age, the only effect, tectonically, of the overthrust is to cause older members of the Torridonian to overlie younger. In most places the shales have been brought to rest on the sandstones, and the displacement is accordingly easy to follow. (See sections, figs. 4, 5; also fig. 22, below.)

The cataclastic effects and other indications of mechanical disturbance in the overthrust rocks are usually of a striking kind, their nature varying with the lithological characters of the rocks.

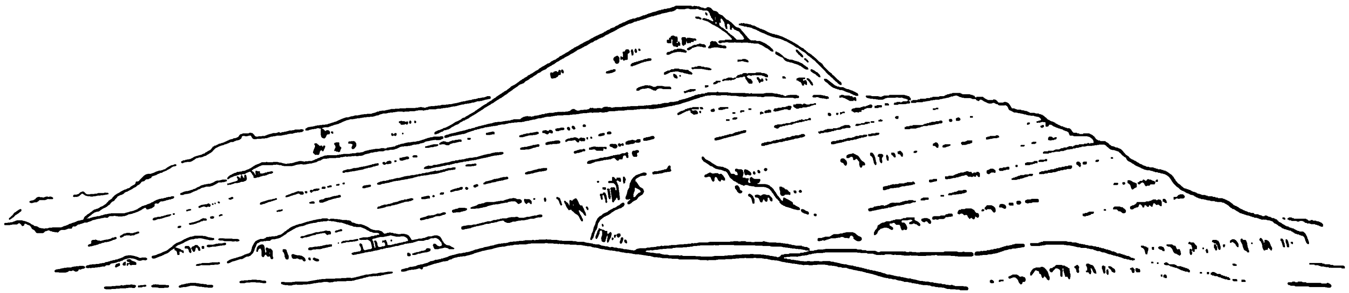
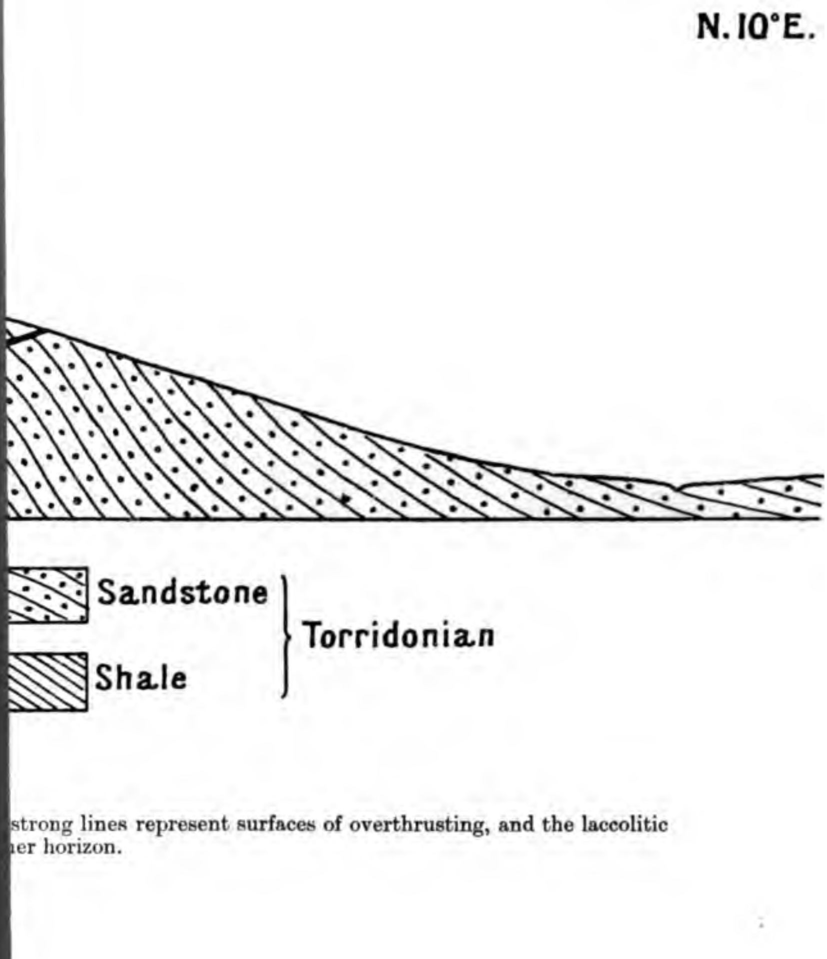
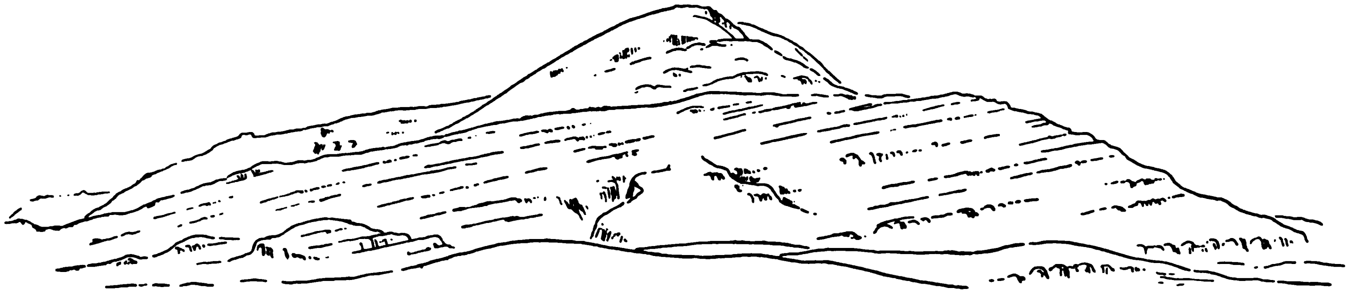


FIG. 3.—Outlines of Sgùrr nan Gillean, Rum, seen from the south, from Loch Dubh an Sgòir.

All the nearer ground is made by unmoved Torridonian sandstones, dipping regularly to the north-west. These are sharply cut off by the surface of overthrust, and the upper part of the mountain shows, in succession, gneiss (intruded near the surface of over thrust), crush-breccia (making a distinct shoulder), and porphyritic quartz-felsite (forming the summit and extending northward). The rough hills to the left, beyond Papadil, are of peridotite.



strong lines represent surfaces of overthrusting, and the laccolitic
er horizon.



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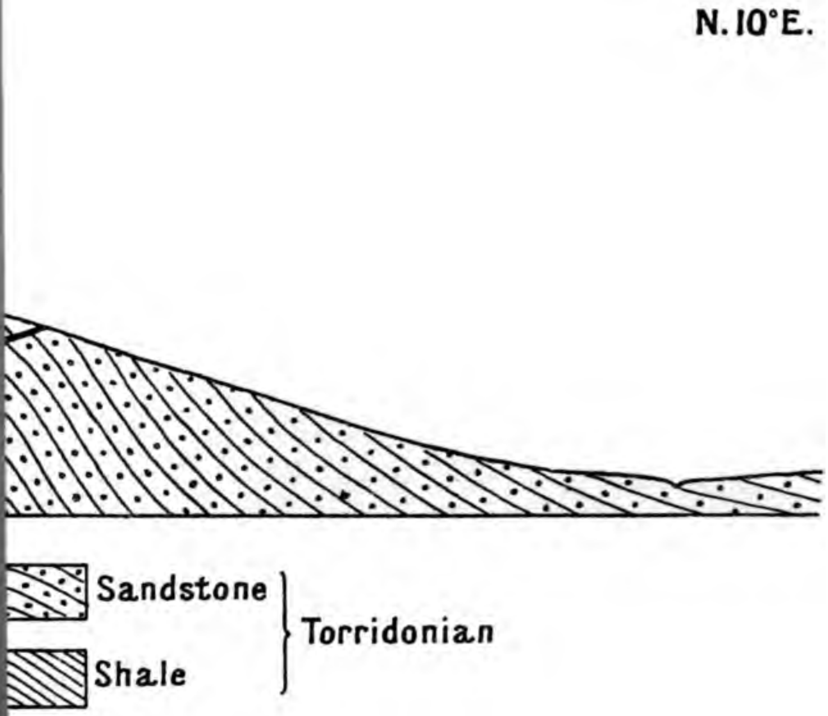

strong lines represent surfaces of overthrusting, and the laccolitic
er horizon.

Where bedding is still recognisable, it is highly inclined or practically vertical. Its strike is not always the same: in many places it corresponds with the mountain-border, *i.e.*, with the circumference of the ideal circle mentioned above. In the Dibidil neighbourhood, where the disturbance reached its maximum, there are often rapid changes of strike. The steeply inclined overthrust shales often have a deceptive appearance of regular parallel bedding, which closer examination resolves into sharply compressed acute isoclinal folding. In other places the shales are brecciated. This latter is the common effect in the sandstones, especially in those of finer grain, the coarse pebbly beds sometimes showing little sign of mechanical disturbance beyond very steep dips. Crush-breccias are among the most conspicuous features of the overthrust belt, and in places occupy considerable areas. Some are composed exclusively of sandstone, others of sandstone and shale, or exceptionally of shale alone. A good example of a mixed breccia is the lenticular mass, a mile in length, which crosses Coire Dubh (the Black Corrie). Such a mass is doubtless produced by the breaking up of the alternations of shale and fine sandstone, which occur at the top of the shale group, or form passage-beds to the sandstone group above. Fragments of sandstone are embedded in a darker matrix, chiefly of crushed shale; though shale fragments also occur, and comminuted sandstone has contributed to the matrix. Some crush-breccias on the slopes of Sgùrr nan Gillean present a peculiarity at first much less easily explicable, for they include in places abundant fragments of gneiss, beyond doubt identical with the Tertiary gneiss intrusive in the breccias in the immediate vicinity. This is part of the evidence that there has been in this district a later system of crust-movements, accompanied in places by brecciation, on the same lines as the earlier and more imposing system. The question will be further considered below (Chap. IX.).

In this place we may mention the thermal metamorphism which has often affected the Torridonian strata in consequence of the great Tertiary plutonic intrusions. The effects are to be observed in the relatively unmoved strata as well as in the highly disturbed; but much more frequently in the latter, since it is among these that the igneous rocks are most usually intruded. The shales become highly indurated, or even assume a flinty consistency. The red sandstones are invariably bleached to a greater or less distance from the contact, corresponding in a general way with the magnitude of the intruded mass. In some places the sandstones seem to have suffered little mineralogical or microstructural change; but elsewhere the more siliceous sandstones have given rise to quartzites, and the more felspathic have undergone rearrangement in varying degree. Not infrequently these latter present in the field a curious resemblance to spherulitic granophyres. Microscopic examination shows that the felspar has been fused and recrystallised in little rods, often with a radiate arrangement. The quartz-grains usually remain intact, and may serve as centres to the radiate growths.

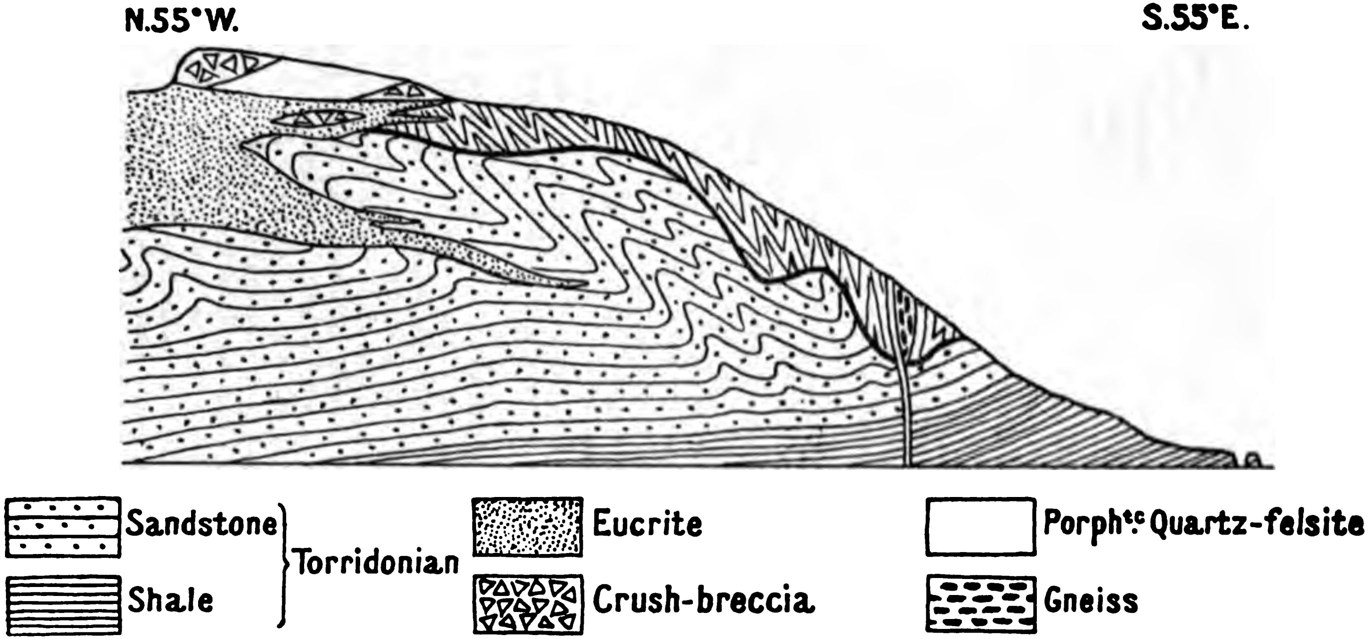

FIG. 5.—Section through Beinn nan Stac to the coast at Stac nam Faoileann, Rum. Scale, 6 inches to a mile.

The strong line represents the undulating surface of overthrust.

It remains to describe the isolated area of overthrust rocks in the north-western part of the island. It measures about a mile by two-thirds of a mile, and forms part of the hilly moorland called Monadh Dubh, between Kilmory and Guirdil. It may be regarded as of the nature of an outlier, but cut off to the north-west by the sea. The outcrop inland of the surface of overthrust is easily traced, being marked by a continuous escarpment. On the eastern side the line is very irregular in ground-plan, conforming with the shape of the ground in a manner which proves that the general inclination of the surface of overthrust does not differ much from that of the hillside. The overthrust-surface in fact dips north-westward from an altitude of 800 feet to sea-level, first gently and then more decidedly, to an angle of about 20°. Below are the ordinary red sandstones of the district, showing little sign of any unusual disturbance. The overthrust rocks above are greatly crushed, though in different degrees. They divide into three members, which have the regularity of a stratigraphical sequence, though the arrangement is clearly a result of crust-movements. We take them in ascending order. (See fig. 6.)

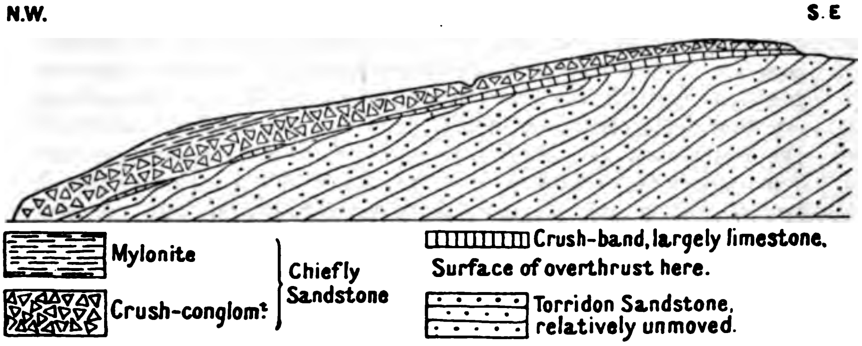
N.W.
S.E
Mylonite
Crush-conglomt
Chiefly Sandstone
Crush-band, largely limestone.
Surface of overthrust here.
Torridon Sandstone, relatively unmoved.

Fig. 6.—Section through the overthrust Torridonian tract of Monadh Dubh, in the north-western part of Rum. Scale, 6 inches to a mile.

(*a*) Crush-band, composed largely of limestone. This basal band does not exceed a few feet in thickness, and in places is absent. It is best displayed on the eastern side. It consists largely of partially crushed limestone, which is, however, intimately mingled with sandstone, the two rocks being brecciated and in part ground down together. There are also unbroken lenticles of limestone, some many feet in length, containing cherts and undoubtedly belonging to the Cambrian (Durness) Series, which does not now occur *in situ* in Rum.

(*b*) Crush-conglomerate, principally of red Torridon sandstone, 100 to 150 feet. This is styled a conglomerate rather than a breccia, because the fragments are rounded by attrition. Their grinding down has furnished finer material to form a matrix. Limestone fragments are found only in very small proportion, but

Estuarine Series to the Estuarine Series of the Lower Oolites of East Yorkshire.

Hugh Miller visited Eigg in the course of his Free Kirk campaign, and his irrepressible proclivities as a naturalist caused him to make a careful examination of the more interesting rocks in the island. His observations are recorded in "The Cruise of the 'Betsey.'" In this graphic account he specially notes the occurrence of the bed with reptilian remains, which occurs on the north and east shores of Eigg.

In 1851 David Forbes* published an account of these Secondary rocks, and pointed out that the shales on the south side of Laig Bay were of Oxfordian age and overlay the Estuarine Series.

In 1871 Sir Archibald Geikie† made a special examination of the volcanic rocks of Eigg and also prepared a map showing the principal divisions of the Secondary rocks. He also established, for the first time, the relationship between the two groups, pointing out that the Volcanic Series rests on an eroded and inclined surface of the Sedimentary Series, and that the lowest point of this surface, which occurs on the west side of the island, is composed of the highest beds in the stratigraphical sequence.

About this time Prof. Judd‡ began a systematic examination of the Secondary rocks of Scotland and published an account of his work in two papers read before the Geological Society of London. A complete account is given of the Secondary rocks of Eigg, so far as then known, accompanied by a list of fossils from the more important horizons. This remains the most complete work up to the present time.

These rocks have been recently mapped out on a six-inch scale by the Geological Survey, and the whole area carefully hunted for fossils by Mr. Tait, who has made an important addition to our previous knowledge of these rocks by the discovery, at the extreme west end of Laig Bay, of a small patch of Upper Cretaceous material, resting on Upper Oxfordian shales. This discovery is specially important as showing that the relation of the Cretaceous to the Oxfordian in Eigg is substantially the same as in Skye, where Mr. Wedd has found that these same rocks are in conjunction and that there is approximately the same hiatus between them.

The detailed mapping of Eigg appreciably augments the value of that carried out in Skye and the neighbouring isles by Mr. Woodward and Mr. Wedd. The latter geologist was particularly impressed by the persistent strike of the Secondary rocks, which clearly suggested that, if continuous to Eigg, the bulk of the sediments in the latter island would be of Lower Oolitic age, and mainly composed of the Great Estuarine Series. That this is so has long been known, but the laying down of the detailed outcrops on a six-inch map brings out more forcibly this persistent strike, as well as the former great extent of the fan of deposition of the Estuarine Series. Moreover, certain bands have now been shown to be peculiarly persistent in this group; thus the small limestones built up almost entirely of *Ostrea hebridica*, always present in the Skye area, are equally persistent in both Eigg and Muck, and clearly afford a well-defined time-horizon. On the other hand, the Great Estuarine sandstones of Eigg have been found by Mr. Wedd to be much thinner in the Skye area; thus marking local differences in the deposits closer inshore, such as would be expected in deposits of this type, and suggesting, moreover, that Eigg lay nearer the source of the arenaceous material than Skye.

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* *Quart. Journ. Geol. Soc.*, vol. vii. (1851), p. 104.

† Geikie. Tertiary Volcanoes: I. *Quart. Journ. Geol. Soc.* (1871), vol. xxvii., p. 279.

‡ Judd. The Secondary Rocks of Scotland. *Quart. Journ. Geol. Soc.*, vol. xxix. (1873), p. 98, and vol. xxxiv. (1878), p. 273.

The huge gaps in the outcrops of these Secondary rocks, now represented by the sea, may be due solely to erosion; but in view of the fact that the district was one of great volcanic activity, it is quite as likely that powerful faults may have let down great masses of rock beneath the sea, for the phenomenon of "sunk-areas" has been met with again and again in districts of this type.

I. OOLITIC ROCKS OF EIGG.

A. GREAT ESTUARINE SERIES.

As already stated, the Great Estuarine Series may be conveniently divided into four parts—(d), the Upper Shales and thin Limestones; (c), the Limestones; (b), the Great Estuarine Sandstones; (a), the Lower Shales and thin Limestones.

(a) *The Lower Estuarine Shales.*

The Lower Estuarine shales are first met with at the north-west corner of Eigg, where they emerge from beneath the base of the Great Estuarine sandstone. From this point to the east they continue to rise steadily, forming first the lower part of the cliff and later the whole of the undercliff, as well as, at times, a small portion of the great inland cliff. After rounding the north-east corner of the island, these beds begin to sink again, at first slowly and later much faster, finally descending to sea-level about a mile north of Kildonan. A remarkable feature of these shales, both on the shore and in the scars, is the occurrence in them of a great number of thin, intrusive basalt sills, especially in their upper portion, where the sills are at least ten times as numerous as in the far more resistent, overlying Estuarine sandstone. On the north-west shore of Eigg these intrusions form a series of small dip-slope planes, terminated by miniature escarpments facing east, the direction in which the beds are rising. Where the rock, resting on a sill, consists only of shale, this shale is mostly denuded off the dip-slope, and is, so to speak, tucked away at the foot of the miniature scarp of the next overlying sill, and it is thus difficult to examine the contents of the shales on these scars or accurately to estimate the thickness of the beds. Where, however, a sill underlies one of the thin limestone bands associated with the shales, the limestone is largely left coating the top of the sill, and can be easily examined. It can thus be seen that the bulk of the thin calcareous bands is built up of comminuted *Cyrena*, but not far from the summit of the group a *Paludina* band occurs.

The presence of these sills makes it very difficult to estimate the true thickness of the sedimentary rocks, but a good general idea of their composition and mode of occurrence is afforded by a section of a portion of the group exposed, on the east side of the island, in the first stream south-east of Rudha nan Tri Clach. This section was measured by Mr. Tait, who has kindly supplied the following account.

Section on the east side of Eigg, exposed in lower part of stream in raised beach—the first stream south-east of Rudha nan Tri Clach (in descending order):—

	Ft.	In.
42. Limestone,	1	0
41. Black Shale,	3	0
40. Limestone,	1	0
39. BASALT SILL,	3	0
38. Black Shale (obscure),	—	
37. BASALT (obscure),	—	
36. Limestone,	1	0
35. Crumbly Brown Shale,	1	6
34. Limestone,	1	8
33. BASALT SILL,	3	0
32. Black Shale,	1	0
31. BASALT SILL,	0	5
30. Limestone,	1	6
29. Shale,	0	6
28. Limestone,	1	0
27. Fibrous Calcite,	0	3
26. BASALT VEIN,	0	3
25. Black Shale,	0	3
24. BASALT SILL,	4	0
23. Black Rusty Shale,	1	6
22. BASALT SILL,	1	6
21. Fibrous Calcite Layers,	0	6
20. Limestone,	2	0
19. Black Shale,	6	0
18. BASALT SILL,	1	2
17. Limestone, with yellow spots,	0	4
16. Brown Shale,	1	0
15. Cream-coloured Limestone,	0	6
14. Brown Calcareous Shale,	2	0
13. Creamy Limestone, with *Paludina*,	1	0
12. Brown Shale, with Entomostraca and *Estheria*,	2	0
11. Shelly Limestone,	0	7
10. Black Rusty Shale,	1	0

	Ft.	In.
9. BASALT SILL,	2	6
8. Black Rusty Shale,	0	6
7. Light-coloured Limestone,	0	8
6. Fibrous Calcite and Black Shale,	0	3
5. BASALT SILL.	3	6
4. Black Shale, with fibrous calcite,	2	6
3. BASALT SILL,	3	0
2. Black Shale, with fibrous calcite,	3	0
1. BASALT (base not seen),	—	

From the above it will be seen that in a total thickness of rock of 67 feet no less than 22 feet consists of basalt; while the alternation of thin shale and limestone-bands occurs no less than twelve times, showing the incessant slight variation in conditions of deposition.

Local Details.—In the north-west corner of the island, where these beds form scars on the foreshore, the higher bands have yielded (T. 736^{A}–T. 751^{A}) *Anomia æsturina*, Tate, *Cyrena* sp., Gasteropods, Ostracoda, Elytron of Beetle, and Fish-scales.

From the *Paludina* limestone, which is about a foot thick, and a little way down in the group, the following were obtained (T. 721^{A}–T. 728^{A}): *Cyrena* sp. and *Paludina* sp. (Large shells apparently the same as the large species which occurs below the bands with *Paludina scotica* in Strathaird, Skye.)

A little below the *Paludina* limestone (T. 729^{A}–T. 735^{A}): *Anomia æsturina*, Tate, *Cyrena*, Lamellibranch (genus doubtful; cf. *Anatina*). Close by, but at a slightly lower horizon (T. 764^{A}–T. 773^{A}): *Cyrena* (?), *Estheria* sp., Ostracoda, *Hybodus* (tooth).

These shales, limestones, and sills occupy the foreshore for about 600 yards, but beyond this the ground between tide-marks is mostly composed of boulders and sands till Eilean Thailm is reached. Here and there, however, the sediments occur in bare patches on the shore, but they are better exposed on the low cliff just above high-water mark. From the more southerly portion of the latter, in a scar north-west of Dùn Thalasgair, the following fossils were collected (T. 752^{A}–T. 763^{A}): *Anomia* (?). Lamellibranch remains, obscure, *Estheria*, Fish-scales.

About 200 feet up from the scars near this point a small seam of ironstone is well exposed, which yielded *Cyrena* (cf. *cunninghami*, Forbes), *Estheria* sp. (T. 635^{A}–T. 640^{A}).

Nearer Eilean Thailm, at the foot of the small cliff, the following were obtained (T. 560^{A}–T. 634^{A}): *Anomia æsturina*, Tate, *Myoconcha*, *Cyrena* (two or perhaps three species), *Paludina* sp., *Nerita arata*, (?) Tate, Gasteropoda (genus doubtful, like one occurring in the white sandstone south side of Musical-sand Bay), *Estheria*, Ostracoda, Fish-remains.

Considerably to the east of Eilean Thailm a small parting of shale and buff limestone occurs between the columnar quartz-porphyry and the thick basic sill shown on the map. From this parting the following were collected (T. 641^{A}–T. 671^{A}):

Myoconcha (?), Lamellibranch remains, Gasteropod casts. Fish-remains (chiefly scales). These scales resemble those from the shale just below the Inferior Oolite sandstone at Elgol, Strathaird.

It was on the foreshore of this locality that Hugh Miller[*] found the loose blocks containing abundant reptile remains, though it is not clear whether these are cast-up boulders or masses fallen from a slightly higher horizon. Mr. Tait found these loose blocks abundant between Eilean Thailm and Kildonan. They are composed of a shelly limestone containing small gasteropods, and have yielded the following fossils (T. 2481^{A}–T. 2905^{A}):—*Unio* sp., *Cylindrobullina inermis* (?), Tate sp., *C.* sp., *Neritina staffinensis*, Tate, *Viviparus* sp., Gasteropoda (small naticoid shells, very abundant), *Acrodus* sp., *Hybodus* sp. (teeth and spines), Fish-teeth (with resemblance to *Saurichthys apicalis*, Ag.), Fish-remains (indeterminable), Crocodilian (?) tooth, Dinosaurian (?) vertebra, Reptilian remains (vertebræ and bones, mostly fragmentary, and teeth).

On his second visit to the island Hugh Miller found this Reptile-bed *in situ* on the east shore, north of Kildonan; and the locality has since been identified by Mr. Tait, who supplies the following note:—"The section extends uninterruptedly from the lochan on the raised beach a quarter of a mile south of Rudha nan Tri Clach southward to where a creamy-white limestone is seen on the top of a basalt sill in the small raised-beach cliff a few yards back from high-water mark. The beach is thickly strewn with blocks and boulders, which hide the beds unless the shore is closely examined." The section has the advantage of showing the relative positions of the parting of shale and buff lime (fish-bed) and the bed from which the blocks with reptile remains were derived.

From this second locality on the east shore of Eigg the following fossils have been collected:—

(I.) Beds below the Reptile-bed (T. 2906^{A}–T. 2915^{A}): Gasteropoda (indeterminable fragments), Cœlacanth scales, Undina (?) (determined by Dr. A. Smith Woodward).

(II.) From the Reptile-bed *in situ* (T. 2916^{A}–T. 2935^{A} and T. 2972^{A}–T. 2976^{A}): *Myoconcha* sp., *Unio* sp., *Cylindrobullina* sp., *Neritina* sp., *Valvata præcursor*, Tate, *Viviparus* sp., Gasteropods (small naticoid shells very abundant), *Lepidotus* (?), Fish-remains (indeterminable), Pterodactylean bone, Reptilean vertebræ and bone.

(III.) Between the Reptile-bed and the Fish-bed (T. 2936^{A}–T. 2942^{A}): *Anomia æsturina*, Tate, *Cyrena* sp., *Ostrea* (*Alectryonia*) sp.

(IV.) Fish-bed, same locality (T. 2943^{A}–T. 2961^{A}) *Myoconcha* n.sp., *Unio* sp., *Viviparus* (cf. *aurelianus*, Cossm.), *Acrodus leiodus*, A. S. Woodward, *Hybodus* sp., *Lepidotus* sp., and Fish-remains (indeterminable).

(V.) One foot above the Fish-bed (T. 2962^{A}–T. 2968^{A}), same locality: *Cyrena* (?) *Myoconcha* n.sp., Lamellibranchs (genus undetermined).

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[*] *Cruise of the 'Betsey,'* p. 75, and again p. 219 (1858).

From the beds enumerated in the type section, previously given on page 20, the following were collected (T. 3183^A–T. 3196) *Cyrena* sp., *Viviparus* sp., Ostracoda, *Estheria murchisoniæ*, (?) Jones, *Hybodus* sp., Fish-remains (fragmentary).

The small group of strata comprising the Reptile and the Fish beds are practically the lowest seen in Eigg; from the nature of their contained fossils it does not seem possible to say more than that we seem still to be dealing with part of the Great Estuarine Series of the Lower Oolite; and probably the true Inferior Oolite of Skye is not exposed, at the surface, anywhere in Eigg.

(b) *The Great Estuarine Sandstone.*

The Great Estuarine sandstone in Eigg has a total thickness of about 200 feet, so far as can be made out by adding together the measured thicknesses of its different parts. It is more or less calcareous throughout, and thin bands or lenticular patches built up mainly of comminuted *Cyrena* may occur at any horizon in it. The rock varies in texture only to a small extent; though a few lines of little pebbles occur occasionally it can hardly be called coarse, but, on the other hand, it never attains the fine grain characteristic of most of the sand-lime bands of the Lias. The composition of this sandstone and the form and size of its component grains have given rise to two curious phenomena for which Eigg has long been famous.

The first of these is due to the amount of lime carbonate present in the rock which tends locally to recrystallise. The calcite is present in sufficient quantity at two horizons to bind the sand-grains together, forming large concretionary masses, at times 20 feet in diameter. These weather out in the cliffs and on the shore at the north-west end of the island, and a graphic description of them is given by Hugh Miller.* Within the largest of these concretions the sand-grains are now set in crystals of calcite, which can be seen on a freshly fractured surface to be at least three inches across. Within the more calcareous portion of the sandstone the concretions are rounded, but have grown so as to interfere with one another, producing at times a compound mass resembling a huge specimen of kidney iron-ore in form. A group of these concretions has been developed beneath a hard, less calcareous, band, which projects from the cliff-face like a shelf. Beneath this band a number of these concretions have been developed, and have weathered out, and these now present the appearance of huge wasps' nests suspended from the lower side of the shelf.

The second phenomenon depends on the fairly uniform size and form of the quartz-grains in the sandstone. When these are set free by weathering they give rise to a sand which emits a curious note when walked on. The phenomenon may be best noted in the small bay of Camas Sgiotaig, called the bay of the musical sand. The phenomenon has been noted by a host of observers, and has given rise to much learned discussion.

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* *Cruise of the 'Betsey,'* pp. 56-57 (1858).

The Estuarine sandstone does not form quite an unbroken mass. There are a few quite subordinate gritty-shale partings, which enable it to be subdivided for convenience of examination and description. Four members may be recognised.

The exact thickness of the lowest division is difficult to ascertain; it seems to be about 100 feet, or rather less. In the upper part of it the strange concretions already described attain their greatest dimensions. This portion of the sandstone can be best examined at the extreme west point of the north coast of the island, where it forms rather broad scars, in which fragments of plant-remains can at times be found in considerable numbers. These plant-remains were examined by Prof. Seward, who supplied the following note on them for Mr. Harker's paper "On the Geological Structure of the Sgùrr of Eigg."* "Imperfectly preserved coniferous wood. The material is not sufficiently good to enable one to determine the nature of the plant with any certainty; it is indubitably a conifer, and from its arrangement of pits on the radial walls of the tracheids I think that it is probably referable to the genus *Araucaroxylon*. This generic type includes *Araucaria* and *Agathis*, the two surviving representatives of the Araucarieæ, and numerous fossil species."

The second division of the sandstone is about 50 feet thick; but it is nowhere well exposed, and, beyond the fact that it contains the usual comminuted *Cyrena* bands, presents no point of special interest.

The third division of the sandstone is about 35 feet thick and separated from the last bed by a variable thickness of gritty shale, at times as much as two feet. The top of the sandstone is grey and somewhat carbonaceous, but it quickly becomes lighter, and contains a thin *Cyrena* limestone (*C. brycei* (?)). Below this the rock is more gritty, and a little above the base is a well-marked pebble-band or bed. Quite at the base is a specially hard and slightly thicker *Cyrena* limestone, seen on the foreshore at the south side of Musical-sand Bay (Camas Sgiotaig).

From this band, in addition to the *Cyrena*, two species of doubtful genus were obtained. One of these (T.776^A) is comparable with R. Tate's *Melania* (?) *inermis* from the Great Estuarine beds of Torvaig near Portree; but it is not identical, and none of these, either from Skye or Eigg, can be referred to genus *Melania* (F. K.).

The highest division is about 30 feet thick, and is a moderately fine calcareous sandstone, forming in fact the upper concretionary zone. It can be best examined on the foreshore at the north side of Laig Bay, where the lenticles and thin seams of *Cyrena* limestone are laid bare, and the fragmental nature of the shells composing them is easily seen. A little carbonaceous material occurs here, but does not present any features of special interest.

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* *Quart. Journ. Geol. Soc.*, vol. lxii. (1906), p. 63.

Other Outcrops of the Sandstone. — From the scar where the lowest division of the sandstone occurs, the bed, or part of it, rises rapidly in the cliff-face, and in this it can be traced continuously, unless covered by scree, along the northern and north-eastern part of the island, finally descending below the sea again on the north side of the Kildonan headland. In this outcrop it is mostly difficult of access, but it can easily be seen that on the eastern side of the island the base of the volcanic series rests on a lower portion of the sandstone than on the western side; and, further, that, as noted by Sir Archibald Geikie, this is due to erosion prior to the pouring out of the lavas. Two small outcrops occur inland of Musical-sand Bay, and are shown on the map. In addition, a very small portion of the Estuarine sandstone occurs on the foreshore just about high-water mark in the north-west corner of Kildonan Bay. It rests on an intrusive sheet, and is both small and thin, and its occurrence in this position is somewhat difficult to explain.

(c) *The Limestone.*

The Limestone group in Eigg has a thickness of about 20 feet. The upper 10 feet is fairly free from admixture with mud and sand material, though it has a very variable aspect. Portions ot it seem to be partly dolomitised, and here and there it is more markedly crystalline.

Some four feet of shale with layers of fibrous calcite intervene between the upper and lower parts of the limestone. The latter is about five feet thick and distinctly sandy; indeed, along certain lines small quartz pebbles are not uncommon, so that it forms a kind of passage rock to the underlying calcareous sandstone. Small bands and lenticular patches almost completely composed of comminuted *Cyrena* occur in both limestone beds.

The limestone is well exposed in the cliffs between Laig Bay and Musical-sand Bay; it can be best examined near the former locality. Its exact mode of ending off inland is not known, as it is either concealed by loose material or covered by a sheet of intrusive dolerite.

(d) *The Upper Shales, with Thin Limestones.*

An almost complete section of the upper shales occurs in the gorge east of Laig Farm, where the junction with the overlying Oxfordian is clearly exposed. These Upper Estuarine rocks consist of alternations of shales and thin impure limestones, and the nature of the whole can be inferred from the following section:—

	Base of Oxfordian above.	Ft.	In.
12.	Dark Shale: *Estheria* sp. and Ostracoda (T. 696^{A} and T. 714^{A}),	3	0
11.	Dark Muddy Limestone,	1	6
10.	Dark Shale, calcareous,	5	0
9.	Dark Limestone, shaley partings,	3	0

	Ft.	In.
8. Dark Shale, limey band at base,	4	0
7. Dark Shales,	5	0
6. Band of *Ostrea hebridica* (T. 715^{A}–T. 718^{A}), resting on cement-stone,	1	0
5. Dark Shale (about)	10	0
4. Easily-disintegrated *Ostrea hebridica* bed,	4	0
3. Dark Shales,	5	0
2. Hard bed of *Ostrea hebridica*,	1	0
1. Shales (not seen at this locality),	10	0

The shales frequently contain a considerable number of Ostracods, and both shale and limestone contain numerous fossils; but the number of species is on the whole singularly small. Like the rest of the Estuarine Series, these beds show the peculiar tendency for one or two species to occur abundantly almost to the exclusion of all others, and this fact is specially well shown by Bed No. 4, which is made up almost exclusively of *Ostrea hebridica.*

The Upper shales are exposed again in a small gully some 200 yards north of the gorge, but are unknown elsewhere. The *Ostrea* beds, however, have a somewhat wider extension. The thicker band is exposed in the side of the road leading to the Catholic Chapel in Cleadale, and from this point it can be traced some distance in the adjacent field, where it was formerly quarried, and part of the wall close by built of it. Though it is not actually seen, small hollows mark the position of these oyster-beds for some distance further north; and both of the thicker ones were cut open when making the ditch to drain the more northerly of the peat-filled hollows in the centre of Cleadale. Beyond this point their position is not known.

B. OXFORDIAN.

The Oxfordian strata in Eigg may be conveniently divided into two parts: a lower (*a*) consisting of harder rocks, limestone and calcareous sandstone, of littoral origin and with few pelagic fossils; and an upper (*b*) composed of very soft shales or clays, in which pelagic forms are locally abundant and permit of a correlation with strata as far away as Buckinghamshire.

(a) *Limestone and Calcareous Sandstone.*

The lower portion of these rocks is seen only in and about the little gorge to the east of Laig Farm, and consists of a bed of limestone, some eight feet thick, beneath which are some 12 feet of calcareous sandstone, the latter resting on the Estuarine shales. The limestone, which lies at the base of the columnar dolerite sill here, is very compact and a cement-stone in part; minute pebbles occurring along certain bands. Although no fossils can be seen in it by the unaided eye, a microscopic section shows it is essentially organic, and there are present in it foraminefera and possibly small chips of crinoids. A few grains of glauconite are also present. The calcareous sandstone is largely built up of easily visible grains, or minute pebbles of quartz, set in a fine matrix of calcareous sand. In all but the lower part of the rock fossils are very scarce, though fragments of Belemnites are not uncommon. The aspect of these often suggests that they may be derivative. At the base of the sandstone is a band of different appearance. This is yellowish on the exterior; but the centre of a large block is distinctly greenish (glauconitic), and the whole has a somewhat phosphatic aspect. In it occur a number of rounded patches, not sharply defined, which seem to be fragments of a slightly older sediment, which should serve to bridge the gap between this local base of the Oxfordian and the underlying Estuarine rocks. Outside the mouth of the gorge these rocks can be traced for a short distance only, and they are unknown elsewhere in the island. Their age is discussed later on.

From the base of the calcareous sandstone in the gully due east of Laig Farm Mr. Tait obtained the following fossils (T. 673^A–T. 695^A):—*Terebratula* sp., *Ostrea* sp., *Cucullæa* sp., *Astarte* sp., Lamellibranch, Gasteropod, *Belemnites* sp., *Ichthyosaurus*, Reptilian tooth, fragment of bone.

(b) *Shales.*

The upper part of the Oxfordian group present in Eigg consists almost entirely of soft friable dark-grey shales, closely resembling their time-equivalent in England, but, strangely enough, differing somewhat from the beds of the same age in Skye, which Mr. Wedd describes as distinctly harder. The highest beds of the Oxford clay occur at the west end of Laig Bay, underlying the Cretaceous sandstone to be described. Farther east the shore of Laig Bay is covered with sandstone boulders, indicating the presence of a soft and easily eroded rock, which can only be the Oxford clay continued from the last exposure. A good deal farther east, still on the south side of the bay, is the best-known outcrop of these beds. This locality can be easily identified by the presence of one prominent basalt dyke, which even at half-tide projects conspicuously, while two others are easily visible when the sea is farther out. These together form the first group of dykes on the south side of the bay, proceeding westward from Laig Farm. Owing to their hardness, they have acted as a protecting core to one large and several smaller patches of the comparatively soft Oxford clay. This outcrop is considerably obscured by boulders and seaweed, and the latter is specially troublesome in summer-time. There is, however, far less of it in early spring, when these beds can be more conveniently examined. Even in summer there is no difficulty in finding numerous specimens of a cordate Ammonite, a large Belemnite, and a *Pecten* (species given below), which serve to fix the horizon of the rocks.

	Ft.	In.
8. Dark Shale, limey band at base,	4	0
7. Dark Shales,	5	0
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The following fossils have been collected by Mr. Tait from these Upper Oxfordian beds:—

I. South side of Laig Bay, east side of Clach Alasdair, among dykes and sills between tide-marks (T. 2977^{A}–T. 3080^{A}):—

Astarte sp. (small, strongly ribbed), *Cucullæa* sp., *Grammatodon* sp. (cf. *Arca pomona*, de Loriol), *Gryphæa dilatata*, J. Sow., *Isocardia* sp., *Nucula* sp., *Pecten* (*Camptonectes*) sp., *Pholadomya* sp., *Pteria* (*Oxytoma*) *inæquivalvis*, J. Sow. sp. (forma *expansa*, Phillips), *Thracia depressa*, J. de C. Sow. sp., *Cardioceras cordatum*, J. Sow. sp. (two forms, coarsely and finely ribbed), *Cardioceras excavatum*, J. Sow. sp., *Belemnites hastatus*, Blainv., *B. oweni*, Pratt.

II. East of Clach Alasdair, about 50 yards east of the preceding locality (T. 3099^{A}–T. 3182^{A} and T. 3323^{A}–T. 3338^{A}):—

Plant-remains, *Cidaris* sp. (spines), *Serpula* sp., *Anomia* sp., *Arca* sp., *Astarte* sp. (small, coarsely ribbed), *Exogyra* sp., *Grammatodon*, sp. (cf. *Arca pomona*, de Loriol), *Lima* (cf. *rigida*, J. Sow. sp.), *Lima* sp. (cf. *L. sublævis*, Thurm., of de Loriol), *Nucula* sp., *Ostrea* (*Alectryonia*) *gregaria*, J. Sow., *Pecten* (*Camptonectes*) *comatus* (?) (Munst.) Goldf., *Pinna* sp., *Protocardia* sp., *Pteria* (*Oxytoma*) *inæquivalvis*, J. Sow. sp. (forma *expansa*, Phill.), *Aspidoceras perarmatum*, J. Sow. sp., *Cardioceras cordatum*, J. Sow. sp. (two forms, coarsely and finely ribbed), *Belemnites oweni*, Pratt., Crustacean remains (fragmentary), *Hybodus* sp. (teeth).

III. Between tide-marks in the little indentation of the shore, about midway between Clach Alasdair and Laig Farmhouse (T. 3265^{A}–T. 3322^{A}):—

Plant-remains, *Pteria* (*Oxytoma*) *inæquivalvis*, J. Sow. sp. (forma *expansa*, Phill.), *Cardioceras cordatum*, J. Sow. sp., *Cardioceras excavatum*, (?) J. Sow. sp., *Belemnites abbreviatus* (?), Mill., *B. hastatus*, Blainv., *B. obeliscus*, Phill., *B. oweni*, Pratt.

The following note on these lists of fossils is supplied by Dr. Kitchin:—"Although these lists have been given under the heading 'Oxford Clay,' it seems by no means unlikely that the Oxford clay in Eigg may be equivalent to our uppermost Oxford clay of England and a portion at least of the Ampthill clay as well. The paucity of species in Eigg makes a comparison difficult, but the predominance of *Cardioceras cordatum* suggests a very high horizon in the Oxford clay, and the occurrence of *Cardioceras excavatum* suggests that the equivalent of still higher beds may be included. *Cardioceras excavatum* is typically developed in the Ampthill clay in Bedfordshire and Huntingdonshire, and it is doubtful if Ammonite stocks of *cordatum* type ever reached the *excavatum* phase of development at a period earlier than that of the Ampthill clay. The occurrence of *Aspidoceras perarmatum* is compatible with the later age, but does not furnish conclusive proof."

Comparison of the Oolitic succession in Eigg and Skye.

Some difficulty has been experienced in fixing exactly the age of the Estuarine Series. That the bulk of them are of Lower Oolite age is certain, but it is possible, and in the opinion of Mr.

Wedd probable, that the highest beds may be of Middle Oolite age, though the fact can not be proved owing to the pelagic forms, which give a time-standard, being replaced by estuarine forms which do not. Moreover, the fact that the Estuarine sandstone is so much thicker in Eigg than in Skye suggests proximity to a shore, and again the pelagic forms of the Inferior Oolite may be lost and the horizon represented in Eigg, but the associated fossils give no true time-standard. The difficulty will be best understood by comparing the rocks from Eigg and Skye as shown in the subjoined table; the Skye section being supplied by Mr. Wedd.

EIGG.	SKYE.
(*a*) Soft shales with an Upper Oxfordian fauna, and possibly belonging in part to an even higher horizon.	Harder shales, but with the same fauna, suggesting the presence of some beds slightly above the Oxfordian.
(*b*) Limestone and calcareous sandstone. No good distinctive fossils, but the abundant fragmental Belemnites suggest this is the same bed as the Belemnite-bearing rock of Skye.	Shaley and calcareous sandstone; passing to calcareous sandstone, which is coarser and pebbly towards the base. Fossils here are still of Upper Oxfordian age. Belemnites abundant, but often difficult to determine.

CHANGE TO ESTUARINE FAUNA.

		Ft.
(*c*) Shales with thin limestone bands, about 20 feet.	Shaley marl and calcareous nodules, - - -	35
	Thin alternating bands of shale, muddy limestone (*Paludina scotica*), and calcareous sandstone, -	37
	Thin shales and limestones, - - -	40
	Total, - - -	212

(*d*) The shales with *Ostrea hebridica* limestones, about 15 to 20 feet: a singularly persistent horizon over much of the Western Isles, but gives no time-horizon.

	Ft.		Ft.
(*e*) Limestone, - -	20	Alternating blue sandy limestone, calcareous sandstone, and dark shales (*Cyrena* limestones), - - -	70
Passes to the Great Estuarine sandstone, -	200	Mainly shales, but with *Cyrena* beds throughout; occasional thin bands of calcareous mudstone, - - -	200
Underlain by more than 200 feet of shales, the details of which have been already given.			

EIGG.	SKYE.
	[*Abrupt Change.*] (*f*) Inferior Oolite:— Hard white sandstone with some plant-remains, about 40 feet, passing to Grey shaley micaceous flags and black shale, with a distinctive Inferior Oolite fauna, 30 feet. This is underlain by some 700 feet of calcareous sandstone and gritty limestone, beneath which are the shales of the Upper Lias, sharply separated from the above.

The full details of the rocks in Skye will be published in the Memoir on that district; but the differences between the latter and Eigg are well shown in the short abstract here given.

It will be seen that the Upper Estuarine shales of Skye attain a thickness of over 100 feet, but in Eigg they are only 20 feet thick. In this case a comparison can be made, owing to the singular persistence of the *Ostrea hebridica* bands. But below this there is no means of making a time-comparison. Similar conditions clearly prevailed over both areas for part of the period, but some of the Eigg shales, as already stated, may well be of Inferior Oolite age.

It may be worth noting that, had not Mr. Wedd succeeded in showing that the Belemnite-bearing sandy beds above the Estuarine shales are really of Upper Oxfordian age, it would seem more likely that the limestone and sandstone of the gorge near Laig Farm represented the Kellaways rock; for Prof. Judd's description of this rock on the east side of the Highlands reads very like the Laig gorge beds, and, moreover, the latter also overlie the Upper Estuarine shales.

In Skye Mr. Wedd found these Upper Oxfordian sandstones reposing so often on the same, or approximately the same, portion of the Estuarine shales, that it seemed likely there was no important break, and the Upper Estuarine shales might be of Middle Oolite age. There does seem more of a break in Eigg, and the 110 feet of Skye have dwindled to 20 feet in Eigg. For this reason it has been thought better to class them, at least temporarily, with the Lower Oolites.—G. B.

II. OOLITIC ROCKS OF MUCK.

The Oolitic rocks of the Isle of Muck have been described by Prof. Judd,* who showed that they belong to the upper part of the

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* *Quart. Journ. Geol. Soc.*, vol. xxxiv., p. 725 (1878).

Great Estuarine Series. They are seen only in Camas Mòr, the principal bay on the south coast of the island, where they form a broad succession of reefs between tide-marks. (See fig. 7.) The strata have a gentle inclination, between 5° and 10°, to north-west, while westward the dips become west and south-west, bringing on higher beds. In addition to this regular succession, which occupies the western half of the bay below the high-water mark, part of the same strata are seen in a much disturbed and altered condition on the eastern side. Here the beds dip at high angles to E.N.E., and they are for the most part thoroughly brecciated, consisting in places of an aggregation of blocks from six feet in diameter downward. Further, the rocks are greatly metamorphosed, owing to an intrusion of gabbro which has invaded them, and forms the cliffs on the east side of the bay.

The strata, as seen in the undisturbed sequence, include a greater thickness than was estimated by Prof. Judd, the section being summarily as follows, in descending order:—

	Feet.
(3) Cement-stone group, - - -	20
(2) *Ostrea hebridica* group, - -	65
(1) Calcareous sandstone group, - -	30
	115

A large irregular sheet of dolerite intruded between (2) and (3) causes some disturbance, but no apparent break in the series.

The lowest beds seen (1) are the equivalents of the Great Estuarine sandstone of Skye and Eigg, but only of its upper portion. Small nodular masses or "doggers" occur at one or two horizons, but none of large dimensions. Towards the top of the group there are two or three thin shaley bands and a bed of small oysters, marking a transition to the overlying succession.

The group (2), characterised by a profusion of *Ostrea hebridica*, consists of oyster-beds separated by dark or lead-coloured shales and occasional bands of cement-stones. The oyster-beds, which make up more than half of the total, are more than twenty in number, the most conspicuous bed having a thickness of nine feet. At the base of the group the oysters are only about a quarter of an inch long; but they grow larger in succeeding beds, and reach at the top a length of about 1¼ inch. In some places the base of a bed consists of fibrous calcite ("beef"). The intervening shales contain abundant *Cyrena* and scattered scales of fish, while *Cypris* occurs at some horizons.

The uppermost beds seen (3) consist principally of hydraulic limestone or cement-stone, but with thin bands of shale and sandstone, the latter enclosing small doggers. Some *Cyrena* and fish-scales are found, and one bed is rich in *Paludina*.

Comparing with the succession on Eigg, as described by Mr. Barrow, it appears that the lowest beds seen at Camas Mòr represent the upper part of the Great Estuarine sandstone; the *Ostrea hebridica* group is the equivalent of the limestone which overlies

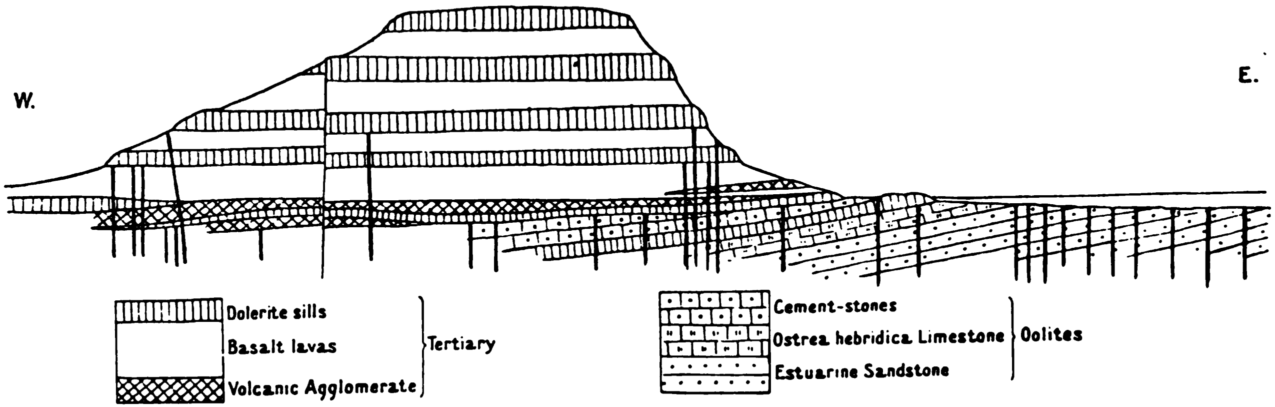

FIG. 7.—Section through Beinn Earrair and Camas Mòr, Isle of Muck. Scale, 12 inches to a mile.

Showing the Jurassic strata and the Tertiary igneous rocks. The vertical lines represent dykes, some of which terminate upward against the volcanic agglomerate or the dolerite sills.

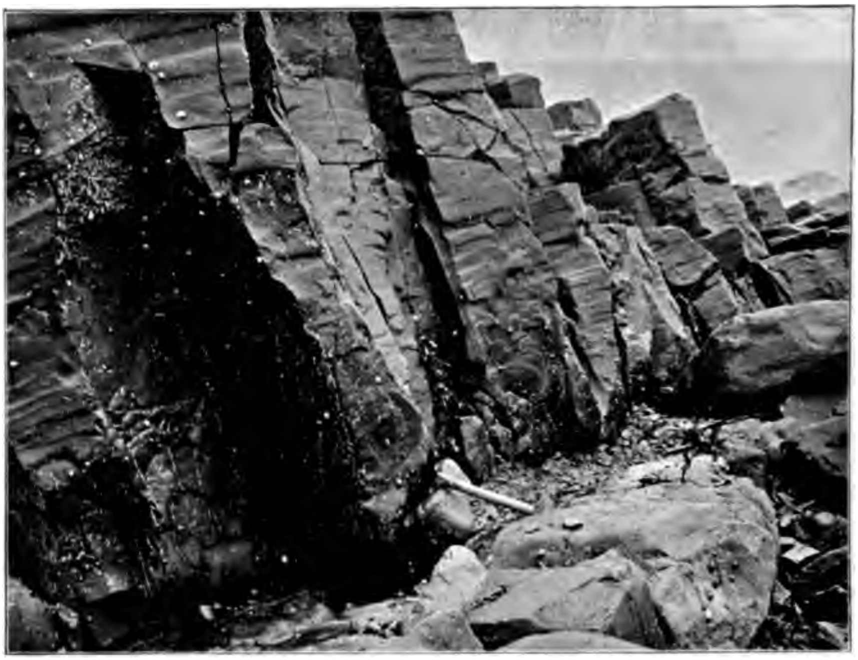

FIG. 1.—Basic sheet (forming escarpment) resting on Cretaceous sandstone (foreground right hand side). Laig Bay, Eigg.

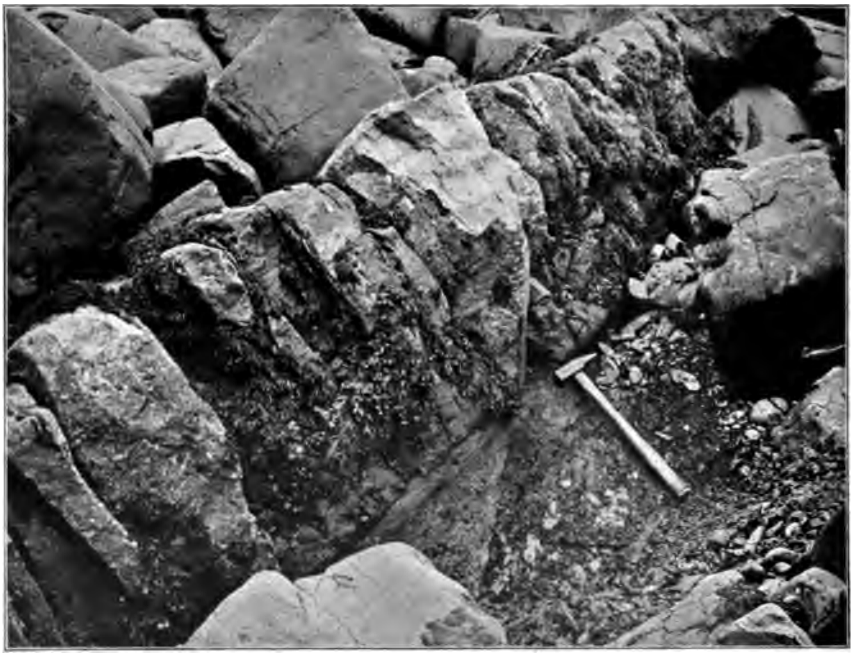

FIG. 2.—Cretaceous sandstone resting on Oxfordian strata. Laig Bay, Eigg.
From photographs by Mr. A. G. Stenhouse.

the sandstone of Eigg, but expanded from 20 feet to 65 feet in thickness; and what has been designated above the Cement-stone group may be correlated with the Upper shales (containing subordinate argillaceous limestone bands) of the Eigg section.

The following fossils, collected by Mr. Tait at Camas Mòr, have been determined by Dr. Kitchin:—

From the lowest beds seen, calcareous sandstone with rounded concretionary masses (T.3252^A–T. 3254^A): Lamellibranchs, indeterminable.

Above the preceding but below the *Ostrea*-beds (T.3248 – T. 3251): *Cyrena* sp. (small triangular form), Ostracoda, *Estheria* sp.

Base of *Ostrea*-beds (T. 3238^A–T. 3247^A): *Anomia æsturina*, Tate, *Myoconcha* (?) Lamellibranch (genus undetermined, identical with specimens T. 734^A–T. 744^A from Eigg), *Aspidorhynchus* sp., *Lepidotus* sp., *Pholidophorus* (?)

In *Ostrea*-beds (T. 3219^A–T. 3220^A): *Viviparus* (?) Ostracoda, *Lepidotus* (?)

Ostrea-beds, above the preceding (T. 3212^A–T. 3218^A): *Estheria murchisoniæ*, Jones.

Ostrea-beds, above the preceding (T. 3202^A–T. 3211^A): *Viviparus* (cf. *aurolianus*, Coss.).

Ostrea-beds, top (T. 3199^A–T. 3201^A): *Viviparus* sp., Ostracoda, *Lepidotus* sp.

Probably from the Cement-stone group; described as from shaley bands in the *Ostrea*-limestones, the top beds of the section west of Sgeir Fhada, near high-water-mark (T. 3227^A–T. 3237^A): *Anomia æsturina*, Tate, *Ostrea hebridica*, Forbes, Ostracoda, *Pholidophorus* sp.—A. H.

III. UPPER CRETACEOUS ROCKS OF EIGG.

Rocks of Upper Cretaceous age are represented in Eigg by some two feet of hard white calcareous sandstone, which occurs at the extreme west end of the scars at Clach Alasdair, at the west end of Laig Bay, and is underlain by a thin deposit of glauconitic sandy mud of older date. This small patch of rock is obviously a remnant only of the original beds of this age; as it contains chalk-flints and, in its mode of occurrence, closely resembles the deposit of the same age in Skye, which is of considerably greater extent. (Plate I.) The specimens were handed to Mr. Wedd, who had examined the material in the latter island, and who has furnished the following notes on the specimens from Eigg:—

"This thin remnant of whitish-calcareous sandstone, with chalky inclusions and siliceous patches and nodules, often of a dark-grey colour, rests upon Oxfordian strata. The rock closely resembles beds of proved Upper Cretaceous age, similarly overlying Oxfordian shales, in the south of Scalpay, and at Strollamus and Strathaird in Skye."

Mr. W. Hill, who has kindly examined our specimens from all these localities, states, of one of the siliceous nodules (T. 602^A) from

Eigg, that it is, in his opinion, an ordinary chalk-flint in which the silica is imperfectly crystallised and that it is full of small globules, such as he has noticed in flints from the Chalk. He believes them to have been globules of colloid silica, the soluble silica having been absorbed into the mass of the flint, so that only imperfectly spherical cavities remain, mostly filled with crystals of an undetermined mineral. He states that while globular silica occurs in siliceous secretions in formations other than the Chalk, he has never met with globules which present the appearances of those in this specimen, except in chalk-flints. He adds: "I feel sure that this flint is the replacement in silica of an originally calcareous deposit, in which I can detect Globigerina and one Rotalian form of Foraminifera, besides prisms of Inoceramus."

In specimens from Scalpay and Strollamus, Mr. Hill noted the same Foraminifera, associated with Textularian and Nodisarian forms. Less than ten feet lower, at the base of the sequence in which these occur in Scalpay, is a thin calcareous grit with *Pecten asper*, &c. As the lowest bed of the Cretaceous in Scalpay and Skye is not older than the Upper Green-sand, while Messrs. E. T. Newton and Hill both recognised a Chalk facies in the microscopic organisms and structure of higher beds in the small sequence there found, these rocks in Eigg can safely be assigned to the Upper Cretaceous, probably to some horizon of the Chalk.—C. B. W.

The presence of a variable amount of glauconitic sandy mud in the rock itself and, still more often, at its base, is of considerable interest, as this material tends to occur in many cases and in many parts of the world, where a considerable hiatus occurs between two deposits, which, apart from their fossil contents, appear to be conformable. In the case of the rock here quoted, the lowest representative of the Cretaceous system, it has now been proved to rest on almost any part of the Secondary sequence from the Triassic to the Oxford clay. It does also rest on the old crystalline gneisses; but the discordance is here, of course, obvious, and it is doubtful if the glauconitic base is in this case present.—G. B.

CHAPTER IV.

TERTIARY IGNEOUS ROCKS: SUMMARY SUCCESSION AND GENERAL RELATIONS.

(i.) SUCCESSION OF EVENTS.

Igneous rocks of Tertiary age constitute the greater part of the land area in this sheet of the map, the only important exceptions being the Torridonian tract of Rum and the strip of Jurassic strata which follows the coast round the northern half of Eigg. On Muck, as we have seen, pre-Tertiary rocks appear at sea-level at one place only, and on Canna and Sanday they do not come into view.

As regards the general development of the Tertiary igneous rocks, the Small Isles form part of an extensive region, embracing most of the Inner Hebrides and the north-eastern part of Ireland. The copious geological literature of the region includes numerous memoirs dealing more or less specifically with the area included in this sheet of the map. A large part of Skye has been surveyed, and the igneous rocks of that island are treated at length in a special memoir to which we shall make frequent reference.* The Small Isles have naturally much in common with Skye and with the rest of the region; but there are special features, which are either peculiar to the area now under consideration, or are better exhibited here than elsewhere.

Igneous activity in Britain during the early half of Tertiary time manifested itself under *three successive phases:* (i.) Volcanic, (ii.) Plutonic, and (iii.) Minor Intrusions. The volcanic rocks, principally lava-flows of basic composition, play a prominent part on Eigg, Muck, Canna, and Sanday, and a few relics are preserved on Rum. During the plutonic phase activity in the British area was restricted to certain specific centres, one of which was situated in what is now the southern half of Rum. In this island accordingly we have a great development of plutonic rocks; while the other Small Isles, with the partial exception of Muck, preserve no record of this phase. The minor intrusions, including sills and dykes, usually of no great size individually but sometimes very numerous, are distributed throughout the area. The remains of a terrestrial flora enable us to assign an Eocene age to the volcanic outbursts; but we have no precise data for fixing the duration of igneous activity or the epoch of its final extinction in Britain.

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* *The Tertiary Igneous Rocks of Skye, Mem. Geol. Sur. United Kingdom* (1904).

There is a further distinction to be observed among the British Tertiary igneous rocks, as has elsewhere been pointed out in the case of Skye.*

Some of the several natural groups of rocks which are to be recognised have a *regional* distribution, in respect of which the Small Isles are merely relics of a much more extensive area throughout which like conditions prevailed simultaneously. Other groups stand in relation with special centres of activity, of which only one is distinctly declared in the Small Isles, viz., that situated in the southern half of Rum. These we shall term *local* groups. For the most part they have their analogues at other special centres in the Tertiary igneous region, such as that of Central Skye; but the precise course of development was not always quite the same at different centres, or at least episodes which are well marked in one case may have left no trace in another.

The following tabular scheme shows the succession of the more important groups in the Small Isles, so far as this has been deciphered. In some cases no satisfactory evidence has been obtained for placing a particular set of rocks in its proper order.

	REGIONAL.	LOCAL.
VOLCANIC PHASE.		Explosive eruptions (volcanic agglomerates) at or near the beginning of the volcanic phase: partly represented by river-conglomerates (rearranged volcanic agglomerates). Feebler and more restricted outbursts recurred later.
	Basaltic lavas; many small flows, collectively of great extent and thickness. Explosive action almost negligible.	
PLUTONIC.		Ultrabasic rocks (peridotites and allivalites).
		Basic (eucrites and gabbros).
		Acid (granites and granophyres).
MINOR INTRUSIONS.	Great group of basic sills (dolerites).	
		Acid rocks (quartz-felsites, &c.).
	Basic dykes, very numerous and of numerous epochs not yet separately recognised.	
		Basic sheets and dykes.
		Ultrabasic dykes (very few).
		Pitchstones and felsites (sub-acid).

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* *Geol. Mag.* (1901), pp. 506-509; *Tertiary Igneous Rocks of Skye*, pp. 5, 15, 419 (1904).

(ii.) GEOLOGICAL RELATIONS OF THE VOLCANIC SERIES.

The volcanic rocks consist mainly of a great succession of lava-flows of basic composition, reaching a total thickness certainly not less than 1000 feet. The mapping goes to show that, as Sir Archibald Geikie has maintained, the lavas emanated from numerous fissures of eruption; and the great aggregate thickness has been built up by the overlapping and overlying of many flows, individually of small size and extent. They do not stand in relation to any particular centres, which might mark the situations of great central volcanoes; nor is there any indication of their dying out in any direction. They are seen truncated with undiminished thickness in the sea-cliffs of Eigg and Canna; and it is probable that the basalts now seen are only relics of one vast lava-field, which had a much wider extension.

Intercalated at various horizons in the basalt succession are accumulations of volcanic agglomerate and breccia, with a general stratified arrangement in most cases, and beds of tuff are associated with these. The latter sometimes pass into shales, often somewhat carbonaceous and sometimes showing fragmentary vegetable remains. The material of the shaley beds is doubtless in the main of volcanic origin, though much decomposed, and these layers, especially in a few places where they become almost leaf-beds, clearly attest terrestrial conditions. The basalts themselves afford confirmatory evidence, for it may not infrequently be verified that the upper surface of a flow was deeply decayed before it was covered by the succeeding flow. These old land-surfaces are preserved at many horizons, and there can be no doubt that the whole volcanic series is of subaërial formation. An interesting circumstance is the occurrence on Canna and Rum of fluviatile conglomerates laid down by rivers of the volcanic period, as was first made clear in the case of Canna by Sir Archibald Geikie. These deposits are in places interstratified with tuffs; and they are also closely connected with the volcanic agglomerates, which probably furnished the material of many of the pebbles.

The volcanic rocks of the Small Isles being fragments of the large region which also includes Skye, the account already given for the latter island is for the most part applicable equally to the former group. In the description which follows we shall accordingly devote most space to those features which are best studied in the area now under consideration, dealing more summarily with the basaltic lavas, which preserve their general characteristics throughout the whole region. Before discussing the rocks in detail, we notice briefly the general relations of the volcanic series as developed in the several islands of the group.

Canna and *Sanday*, which lie nearest to Skye, reproduce on a small scale the general structure of that island, and illustrate well the "plateau" type of scenery. The country is divided into blocks by a number of faults, which run in directions varying between N.N.W.-S.S.E. and N.E.-S.W. Each block is gently tilted so as to give a westerly dip: while the faults, where their effects can be ascertained, generally throw down to the east. Thus, although the geological horizon represented by the lowest rocks at the east end passes below sea-level, it is perhaps not far below even in the extreme west. The base of the series is not seen, but it is likely that the pre-Tertiary foundation is, at least in the east, at no great depth.

In *Rum* the case is very different, for the Torridonian sandstones rise in the north of this island to nearly 1000 feet, and the volcanic series is represented only by scanty relics in the north-west. In the much-faulted ground about Fionn-chrò the base is seen at altitudes varying from 600 to 1000 feet: and there is in addition a patch of basaltic lavas on the north-easterly shoulder of Orval, this being an outlier resting upon the subsequently intruded granite. No relics of the volcanic group have been detected among the plutonic masses of the southern mountains.

In *Eigg* the general dip, still at a gentle angle, is rather south and south-west than west; and the principal faults run north-west–south-east. The most important of these faults cross the middle part of the island, and have doubtless helped to determine the depression between Laig and Kildonan. The base of the volcanic series, resting on Jurassic rocks, is seen in the northern half of the island, and rises in the Dun Thalasgair escarpment to an altitude of about 400 feet.

On the comparatively low-lying isle of *Muck* the rocks are for the most part nearly horizontal, or have a very slight inclination to north-west. The Jurassic strata below are seen only near sea-level in Camas Mòr, as already described; but it is probable that they are not far below water along all the southern and eastern coasts.

Viewed broadly, the group of the Small Isles is part of a relatively depressed region, lying in a trough between the Outer Hebrides and the Scottish mainland. The limits of this trough of the Inner Hebrides, perhaps corresponding roughly with the eastern and western limits of Tertiary vulcanicity in Britain, cannot be laid down very precisely. The bounding faults are in general concealed beneath the sea; though an important one is seen in Morven, which causes, according to Sir Archibald Geikie's estimate,* a downthrow of more than 1000 feet to south-west.

The relative elevation of Rum, in the centre of the Small Isles, betokens movements of a different and strictly local order, with which the plutonic intrusions in that island are closely connected.

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* *Ancient Volcanoes of Great Britain*, vol. ii., p. 453 (1897).

CHAPTER V.

VOLCANIC AGGLOMERATES AND TUFFS, AND FLUVIATILE CONGLOMERATES.

(i.) CANNA AND SANDAY.

Since the various fragmental and stratified deposits which occur among the basaltic lavas are of local distribution and variable nature, it will be convenient to treat the several islands separately; and we begin with *Canna* and *Sanday*, which present the most features of interest in this connection. The shores and islets of Canna Harbour, which divides the two islands named, afford admirable exposures of the rocks in question, and the cliffs at the eastern end of Canna present a fine natural section. Sir Archibald Geikie* has given a somewhat full account of the interesting group of deposits here displayed, and has pointed out their bearing on the physical geography of the period.

As already remarked, no base to the volcanic series is seen on these islands; but the deposits to be described, underlying the thick pile of basalts in the interior of Canna, probably occupy a position in the lowest part of the succession. It seems likely, however, that the explosive outburst which produced the agglomerates was not the very earliest episode in this district; for, as Sir Archibald Geikie has noted, the blocks of basalt which make the principal element of the coarser accumulations have in great part the characters of material derived from the breaking up of pre-existing flows. Both volcanic agglomerates and conglomerates with water-worn pebbles occur, besides beds of finer material, found especially towards the margin of the area affected. The material of the conglomerates is evidently derived in very great part from the agglomerates, and in some places it is not easy to determine whether this material has or has not been rearranged by water. For this reason the deposits will first be considered as a whole.

The maximum thickness actually seen is at the eastern end of Canna, and it is probable that the greatest development of the group is in this neighbourhood, apart from any possible extension eastward of which the evidence is lost. The fact that in many places the rocks are washed by the sea makes it impossible to follow closely the thinning-out of the group northward and southward; but we may draw conclusions from changes in the nature of the deposits, and especially from the varying degree of coarseness of the accumulations. So far as the data can be trusted, the group seems to be dying out on the north coast of Canna, while

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* *Quart. Journ. Geol. Soc.*, vol. lii., pp. 351-370 (1896); *Ancient Volcanoes of Great Britain*, vol. ii., pp. 218-234 (1897).

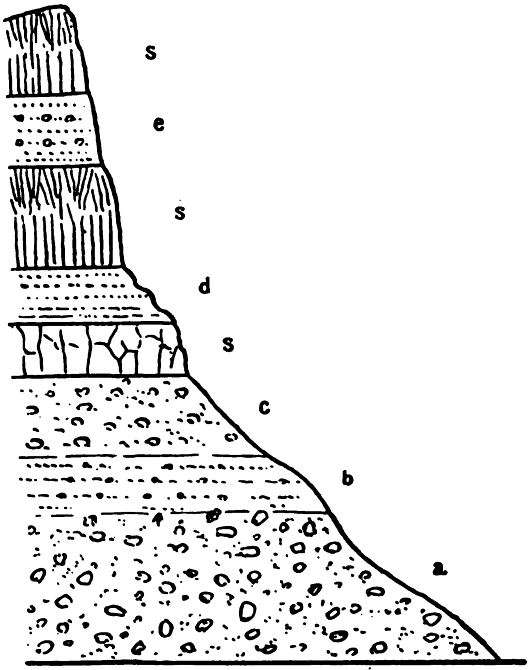

Fig. 8.—Section of cliff at Compass Hill, Canna.

The thicknesses given are only approximate.

s. 60 feet. Sill of porphyritic dolerite, columnar.

e. 50 feet. Conglomeratic or sandy tuff, with coarser and finer bands. Well-rolled pebbles up to six inches in diameter, mostly of Torridon sandstone but some of gneissic and schistose rocks. Little volcanic material except in the matrix.

s. 70 feet. Sill of porphyritic dolerite, columnar.

d. 40 feet. Red ferruginous tuff. Northward it passes into a pebbly or sandy tuff, stratified like that above (*e*). This contains in some beds abundant rolled pebbles of Torridon sandstone up to six inches or more in diameter.

s. 35 feet. Sill of dolerite, rudely columnar, thinning out southward.

c. 55 feet. Agglomerate or conglomerate with little indication of stratification. Blocks and rounded pieces of basalt with a few of Torridon sandstone.

b. 45 feet. Conglomerate or conglomeratic tuff, mostly with well-marked bedding, but lower limit not sharply defined. More or less rounded pieces of basalt, mostly less than six inches in diameter but some up to two feet; in places also red Torridon sandstone, subangular, up to one foot diameter. Abundant matrix of basaltic tuff.

a. 100 feet. Coarse agglomerate. Subangular blocks of basalt up to six feet or more in diameter, and the finer material also of basaltic nature. Torridon sandstone less abundant, in smaller pieces, subangular or rounded.

the south coast of Sanday is probably not far from the southern limit of important deposits of this group. This indicates an extension of some two miles or more from north to south. The extension in a westward direction presents a more difficult problem. Besides the thick dolerite sills, which occupy most of the ground, we cross a number of faults; and the general impossibility of identifying any determinate horizons in the volcanic series makes the effect of these faults a matter of some doubt. The remarkable paucity of dykes on Canna, as noted in a succeeding chapter, affords a certain presumption that the agglomerate may be prolonged westward in some force; but it would not be safe to base any conclusion on such negative and indirect evidence.

The best vertical section of the group is in the cliff which makes the seaward face of Compass Hill, on the east coast of Canna. (See fig. 8.) This is about 450 feet high, and, deducting the thicknesses of three dolerite sills of later age, we have here some 290 feet of agglomerates and conglomerates exposed. The coarsest accumulation is that which forms the lowest 100 feet, extending down to the sea. It is a very coarse agglomerate, the blocks sometimes having diameters of six feet or more, as is well seen in an abrupt knoll which in one place stands out from the base of the cliff (fig. 9). These large blocks with smaller ones, mostly of basalt and subangular in shape, are embedded in a matrix of finer basaltic *débris*. There are also blocks of Torridon sandstone, which are found less abundantly, and do not attain such large dimensions. Their occurrence in this undoubted volcanic agglomerate, a deposit showing no stratification or other sign of water-action, is of interest; for the sandstone fragments in this case can only have been derived from the concealed foundation on which the volcanic series rests. It is important to note further that the sandstone fragments have subangular to rounded shapes, though the attrition thus implied was certainly not connected with the agency of water. A like circumstance is not seldom observed in other volcanic agglomerates of this region.

The coarse agglomerate passes up into a rock (*b* in fig. 8) which must rather be termed a conglomerate, since it is well bedded, and its basalt fragments are all more or less rounded. The very large blocks are not found here or at higher horizons. This conglomerate is, as Sir Archibald Geikie has remarked, not very clearly marked off from the unstratified accumulation below. The appearances suggest that a stream flowed over the incoherent coarse agglomerate, rearranging the upper part of the mass. It seems, however, that another explosive outburst followed, for the conglomerate is overlain by an agglomerate (*c*), not so coarse as that at the base, but equally devoid of any sign of bedding. A dolerite sill is next in the section, its fairly regular coarse marking a well-defined bedding-plane in the volcanic series, and the higher members of that series are very clearly stratified. (See fig. 10.)

The next succeeding member (*d*) is of somewhat variable nature. At the locality of the section it is very ferruginous and of deep-

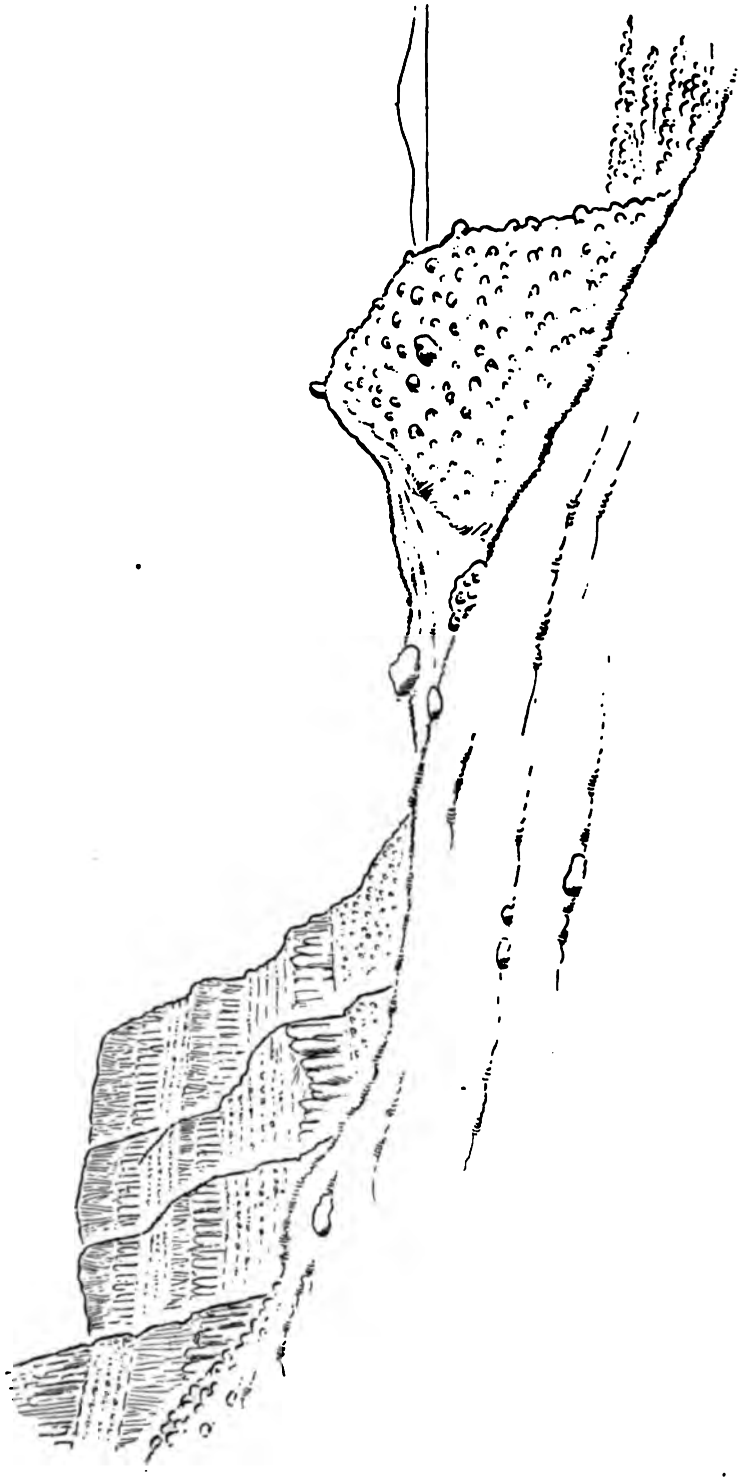

FIG. 9.—Mass of coarse volcanic agglomerate forming the lower part of the cliff at Compass Hill, Canna.

red colour, resembling the weathered crust seen elsewhere at the upper surface of a basalt flow. It is presumably due to a similar decomposition affecting a basaltic tuff. A little northward this deposit passes into a well-stratified sandy and pebbly tuff, which in some bands contains abundant rolled pebbles of Torridon sandstone. This deposit has a thickness of about 40 feet, and is divided by another dolerite sill from a further thickness of 50 feet of similar stratified material, with coarser and finer bands (*e*). The finer are mainly of basaltic tuff, while the coarser have a matrix of tuff enclosing abundant well-rolled pebbles of diameters up to six inches. The sandstone pebbles which have occurred in varying amount in the lower members of the group here become the principal element. Moreover, there are now associated with them other non-volcanic rocks, among which Sir Archibald Geikie identified gneiss, crystalline schists, and epidotic grits, which cannot be matched nearer than on the Scottish mainland.

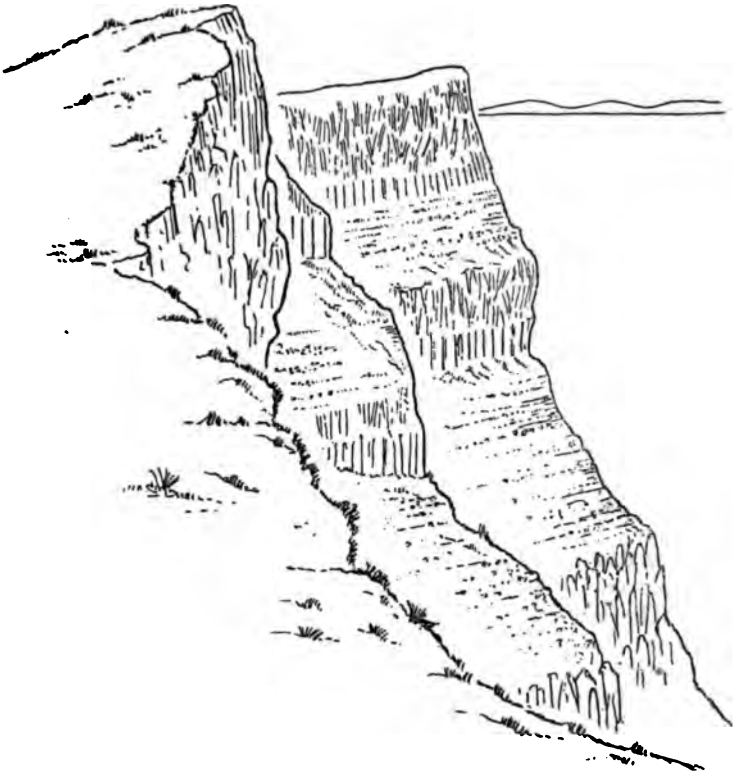

FIG. 10.—Upper part of the cliff at Compass Hill, Canna, showing bedded conglomerates and tuffs with intrusive sills of columnar dolerite.

Disregarding the later sill-formed intrusions, we have in this section an unbroken thickness of nearly 300 feet of fragmental accumulations. The lowest 100 feet is of coarse unstratified agglomerate, and another horizon of agglomerate is found higher up. The rest shows everywhere indications of the action of water, and the general character of the deposits—especially in view of what is seen elsewhere when they thin out—points to fluviatile action. The signs of this action become more marked in the upper part of the section; and here, too, we find proof that a large part of the pebbles in the conglomeratic bands has been transported from a distance.

The above interpretation is essentially that of Sir Archibald Geikie, except that, regarding the columnar sheets of dolerite as lava-flows, he divides the succession into two stages with a certain interval between them. He suggests, with much probability, that the coarse agglomerate at the base, or some part of it, occupies an actual volcanic vent. The relations are not sufficiently well displayed to establish this beyond question, but it is difficult to believe that the very large blocks there seen can have been thrown from any great distance.

Following the coast northward and westward from Compass Hill, the lower part of the group, with large included blocks, can be traced as far as the stack An Stòl. There seems to be no clear indication of fluviatile action here, and we may perhaps consider that the basal agglomerate extends thus far, disappearing near this place. The overlying conglomerates can be traced, in spite of two or three faults, to the more westerly stack Bod an Stòil, where the summit of the whole group comes down to sea-level. There are other occurrences of bedded deposits farther west, presumably brought up by faults; but the inaccessible character of the cliffs makes it impracticable to lay down the relations with any certainty.

Such exposures as have been detected along the northern coast of Canna are, however, sufficient to show that before reaching Camas Tharbernish the whole group has been reduced to a thickness of a few feet, while the conglomerates give place more and more to fine tuffs, often shaley and carbonaceous. Small pebbles of Torridon sandstone are still found, as well as basalt. At one place, near a cave, Mr. Harvie-Brown* discovered a leaf-bed. From here Mr. Starkie Gardner identified two species, both found also at Ardtun, in Mull; and one of them, *Cryptomeria Sternbergii*, is described and figured in his memoir.† Two other localities for plant-remains are noted in Sir Archibald Geikie's paper.

Southward from Compass Hill the lower portion of the group is well seen as far as the crag of Coroghon and the neighbouring stack Alman, where some complication is introduced by irregular intrusions belonging to the dolerite sill group (fig. 34, below). The blocks of basalt here range up to a foot or two feet in diameter, and in most parts of the mass there is no indication of water-action; but on the north side of Coroghon the bedding is well marked, and there are thin bands of tuff and shale intercalated in the coarse accumulation. A like circumstance is to be noted at other localities to the west and south, and it is often difficult to draw any line between agglomerate and conglomerate. The frequent rounding of the included blocks cannot be taken as a proof of stream-action. The most probable interpretation is that the volcanic agglomerate extends for some distance in this direction, and has in different places been more or less rearranged by the agency of running water. It is a point worthy of remark that here, as in Skye, vegetable remains are occasionally enclosed even in coarse volcanic agglomerate. An interesting record of this is preserved in the old *Statistical Account* of Canna, and is quoted below.*

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* *Cit.* Starkie Gardner, *Quart. Journ. Geol. Soc.*, vol. xliii., p. 276 (1887).

† "A Monograph of the British Eocene Flora," *Mem. Palæont. Soc.*, vol. i., pp. 77, 85-89, and pl. x., fig. 2 (1884).

On the hill west of Compass Hill and above Canna House the upper members of the coast-section begin to thin away, and to be replaced by amygdaloidal basalts on the same horizon. This can be ascertained in spite of the strong sills which occupy most of the ground. The dying-out of these upper conglomerates westward seems to be rather rapid, and they are not found in this direction beyond the enclosure of A' Chill. If any part of the fragmental group is prolonged under the interior of Canna it must be the lower coarse agglomerate.

The rocks seen about Canna House and along the north side of the harbour belong doubtless to the lower part of the Compass Hill section, but not the lowest, which has here passed below the sea-level. Blocks up to a foot or even two feet occur, besides smaller pieces of Torridon sandstone. Stratification is evident in places, and there are beds of tuff with only scattered pebbles, small and well rolled. The top of the group as here developed is well shown in a section close to the first cottage from Canna House, and has been described by Sir Archibald Geikie. The section is represented in fig. 11. The tuff resembles those seen elsewhere in this group. Whether close-textured or shaley, it is composed essentially of basaltic material, stained brown by ferruginous alteration. Much of the rock is made up of chips and shreds of basaltic glass, usually vesicular or pumiceous, recalling some palagonite-tuffs of other areas; but there is also a considerable proportion of crystals, well shaped but sometimes broken, especially olivine and augite in a more or less decomposed state. These elements are bound into a coherent rock by a ferruginous cement, and in places a little calcite. One example from this place is studded with little spheroidal spots, like concretions. $\frac{1}{50}$ to $\frac{1}{10}$ inch in diameter and sharply defined. In a thin slice these spots show a clear colourless substance of low refractive index and sensibly isotropic, which is perhaps analcime.*

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* "In Canna there is a great deal of the rock called Plumb-pudding-rock, and that in some places connected with the basaltic rock. A singular instance of this is a steep and lofty rock called Corraudhun [Coroghon Mòr, a little north of the harbour], on the top of which a small ruinous building remains. Not many yards distant from this is a rock of the plumb-pudding kind, which is sometimes surrounded by the sea [Alman]. The side of it next the rock is nearly perpendicular. In this side of the rock, considerably above the level of the sea, there is, in a horizontal position, the remains of a tree, nearly in a putrid state, apparently forming a part of the solid rock, and having at least five or six fathoms of the rock above it. There is no room to doubt that it has been wood, and its fibres have a near resemblance to those of oak."--Rev. Donald M'Lean, in *Statistical Account of Small Isles* (1794), vol. xvii., pp. 272-274.

The fragmental group cannot be followed along the south coast of Canna beyond An Doirlinn (the strait dividing this island from Sanday), its horizon being there below sea-level.

The islets in Canna Harbour seem to preserve parts of the coarse agglomerate which have escaped levelling and rearrangement by water-action. Some of the blocks of basalt here have diameters of three or four feet or more, the occasional sandstone fragments being, as usual, smaller. The neighbouring shores of Sanday, however, round the bay where the crofters' cottages are collected, show only stratified tuffs with few pebbles; and these deposits are already beginning to be replaced by amygdaloidal lavas, which dovetail into the bedded group. On the west and south-west coasts of Sanday the group seems to be much reduced. Bedded tuffs are seen interstratified with scoriaceous basalt, and at the base of Tallabric there is a thin band of agglomerate or conglomerate with no blocks of large size. At one place, in the little bay east of Tallabric, a section, nine feet high, shows conglomeratic tuff in the lower and shaley tuff in the upper part, the well-rolled pebbles, up to three or four inches in diameter, including many of sandstone. Eastward of this place, and of the Catholic Chapel on the north coast, basaltic lavas have for the most part taken the place of the fragmental deposits. The coarse accumulations near the

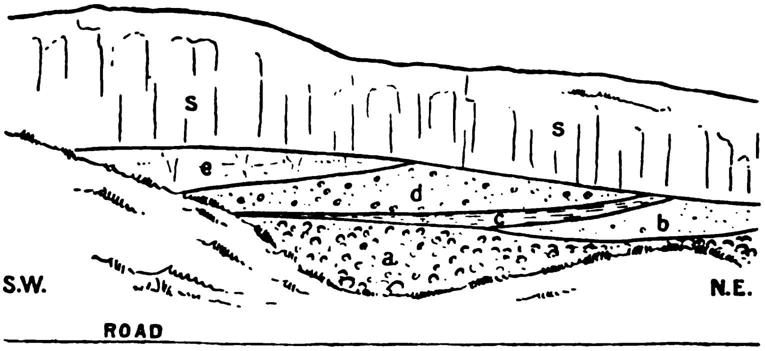

FIG. 11.—Section at the first cottage south-west of Canna House.

s. Dolerite sill.
e. Amygdaloidal basalt lava.
d. Agglomerate, to two feet in thickness, enclosing subangular pieces of the subjacent tuff, as well as rounded blocks of basalt.
c. Shaley tuff, with plant-remains, one foot.
b. Pebbly tuff, to three feet, passing into the coarser deposit below.
a. Conglomerate or agglomerate, with tuff matrix, enclosing pieces of basalt up to five inches or in the lower part one foot, with some pebbles of sandstone.

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* *Quart. Journ. Geol. Soc.*, vol. lii., p. 360 (1896).

base of the group, however, have not yet died out. They are seen at several places in the eastern part of Sanday, passing below sea-level, so that their thickness cannot be ascertained. About Ceann an Eilein and to the north a comparatively coarse agglomerate is seen between tide-marks, containing subangular and rounded blocks of basalt up to two feet in diameter, with some sandstone. The last exposures in this direction are in the stacks Dùn Mòr and Dùn Beag and the neighbouring cliff (fig. 12).

An interesting account of this locality has been given by Sir Archibald Geikie, who sees here evidence of a channel cut in the basic lavas and filled in with river-gravel. Our survey has led to a different conclusion. The strong sheets of dolerite, often with columnar jointing, appear here as elsewhere to be not lava-flows but intrusive sills of later date. Neither here nor in any other part of the Tertiary volcanic region have we found rocks of this description among the blocks and fragments in the agglomerates and conglomerates. The fragmental group at this place has a maximum thickness of perhaps 50 feet, with amygdaloidal basalts both below and above (disregarding the dolerite sills). It thins away rapidly in the cliffs to the west, and on the other side it is cut off by a fault passing immediately north-east of Dùn Beag. At the base there is a small thickness of shaley tuff, with some plant-remains, and above this comes a conglomerate. The latter is in Dùn Mòr about ten feet thick, and sills have been intruded at its contacts with the finer deposit below and the lavas above. In Dùn Beag the conglomerate swells to a thickness of perhaps 40 feet. The upper part is distinctly bedded. The lower part, with blocks sometimes several feet in diameter, shows no perceptible arrangement; but, as Sir Archibald Geikie has remarked, pebbles of foreign travelled rocks prove that the whole has been redistributed by the agency of running water. This thick mass of coarse conglomerate also encroaches upon, and to some extent cuts out, the tuff below; and the lower sill, intruded on this horizon, has been arrested by the obstacle, so that it terminates abruptly. The dying-out of a sill against a mass of coarse unstratified agglomerate or conglomerate is a phenomenon which may be verified at numerous other places in this region. Sometimes, as at Coroghon and Alman, it is accompanied by more remarkable irregularities of behaviour. (See below, fig. 34.)

The coarse conglomerate of Dùn Beag seems to be quite local, and it is probable that we approach here the limits of the group, the bedded deposits becoming interstratified with lava-flows, to which they gradually give place. It appears, then, that the thick succession seen at Compass Hill dies away southward and south-westward on Sanday, as it does north-westward on Canna. We have seen, too, that the upper part rapidly dies out westward. How far the lower part of the group is prolonged in that direction beneath the higher ground of Canna, is a question to which no direct answer has been obtained. Sir Archibald Geikie's argument seems to establish beyond question that these bedded deposits belong to a considerable river which flowed over the

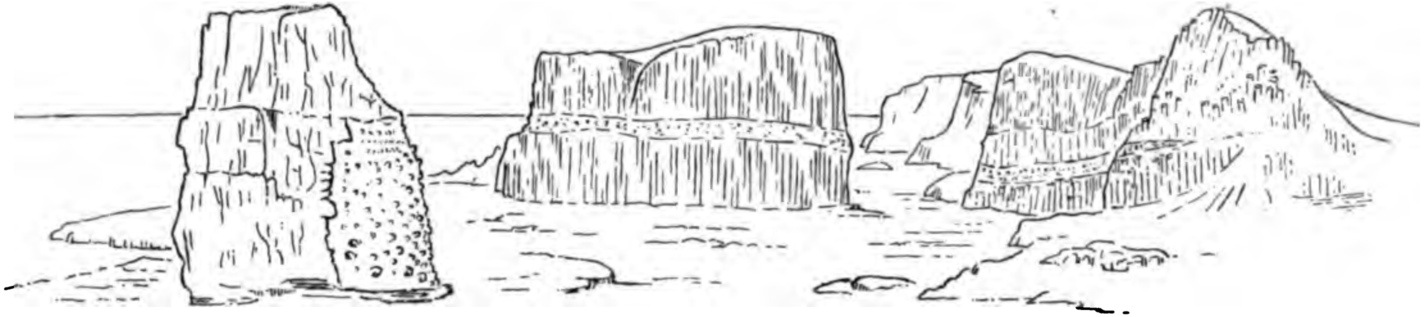

FIG. 12.—Dùn Beag, Dùn Mòr, and the neighbouring cliffs of Sanday; looking south-west.

In the cliffs and in the larger stack a layer of volcanic conglomerate is seen between two dolerite sills. In Dùn Beag this accumulation swells out to a thickness of 40 feet, and the lower sill terminates abruptly against it. The conglomerate and sill are underlain by a bed of shaley and carbonaceous tuff, which rests on a platform of amygdaloidal basalt.

basalt plains during an early part of the volcanic period. Marine agency is excluded by the abundant proofs of terrestrial conditions throughout the whole series. Other considerations adduced are the large size of many of the blocks or boulders, the occurrence of foreign stones (even allowing for the fact that much of the Torridon sandstone may be derived from a subterranean force), and the lenticular character and rapid variations of the deposits themselves. The foreign rocks are of types found on the mainland of Scotland to the east, which affords a general indication of the direction of transport; but the data obtainable on the ground do not suffice to lay down with any confidence the actual course of the river.

Of bedded deposits at higher horizons than that of the Compass Hill group the volcanic series of Canna shows but few examples. In a gully* about 1100 yards S.S.W. of Tarbert Farmhouse a band of conglomerate is seen half-way up the steep cliff. This occurs between two faults, and its precise horizon cannot be fixed. Another exposure, noticed by Sir Archibald Geikie, is seen beneath the dolerite sill which forms Creag a' Chalrn, 500 yards north-east of Tarbert (fig. 13). Here is a shaley tuff with thin carbonaceous seams and enclosing also pieces of wood, which are in a charred condition, owing probably to the immediately overlying sill. There is also a lenticular bed of tuff (*c*) containing numerous small pebbles. We have therefore some evidences of the operation of running water at epochs subsequent to that of the large river.

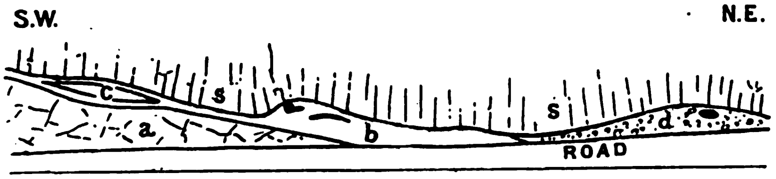

Fig. 13.—Section by roadside at Creag a' Chalrn, near Tarbert, Canna.

s. Base of dolerite sill.
d. Agglomerate of amygdaloidal basalt, enclosing a block of charred wood.
c. Lenticle, eight feet long, of pebbly tuff, in *b*.
b. Dark olive-green shaley tuff, of compact texture, to 2½ feet in thickness; containing a few coaly seams to half an inch and a block of charred wood.
a. Amygdaloidal basalt lava.

(ii.) RUM.

Conglomerates are seen at two places in the outliers of the basalt group preserved in the north-western part of *Rum*, and they not improbably belong to two distinct horizons, though this is not clearly demonstrated.

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* The locality is near Rudha Sgòr nan Ban-naomha, and a precipitous track in the gully leads to the altar for votive offerings, which stands on a low platform or under-cliff.

To the west of the Torridonian hill Minishal a small wedge of the volcanic rocks is let down between two faults, the more easterly of which passes through a little tarn. A low hill overlooking the tarn is made by a sill intercalated in the basalt lavas, and some smaller sills occur below. Beneath the lowest of these, and forming the lower half of the northerly slope of the hill, comes a coarse conglomerate, underlying the basalts and showing a thickness of nearly 150 feet. (See fig. 14.) It contains large pebbles of Torridon sandstone and basalt, with some of granite and a porphyritic felsite; and the matrix, which is of a clayey consistency, seems to be of basaltic composition, but much decomposed. It would be easy to mistake the conglomerate for a boulder-clay, if it were not seen to pass under the basalt with its dolerite sills.

The conglomerate is cut off by a fault to the north, and amygdaloidal basalts are seen in the burn. On the opposite bank a small section between two faults shows two thin beds of conglomerate, surmounted by a tuff also containing abundant small pebbles of basalt, porphyritic felsite, &c. The faulted nature of the ground in this neighbourhood makes it a matter of some difficulty to determine the precise place in the succession of the fragmental accumulations. It is probable, however, that they are not far above the base of the volcanic series at this place.

The second locality is some distance farther west, at the northern base of Fionn-Chrò. This hill is built up by a succession of sheets of a peculiar rock of the mugearite type; and immediately below this, on the north side, occurs a river-conglomerate with well-rolled pebbles. The matrix seems to be mainly of basaltic tuff, and there are intercalated tuff-bands almost free from pebbles. This conglomerate, at an altitude of about 1000 feet, is underlain by amygdaloidal basalts. Faults cut off the rocks on the north side, but on the west we can pass down from the conglomerate to the base of the basalt group, resting on the Torridon sandstone above Guirdil. It appears that this conglomerate is about 300 feet up in the succession, and may be at a higher horizon than the former occurrence. This conclusion is not, however, necessary, for the pre-Tertiary land-surface, on which the volcanic rocks were formed, may have presented considerable inequalities. If the first conglomerate noticed is, as supposed, low down in the series, it must die out very rapidly westward; for within 500 yards, at the eastern base of Fionn-Chrò, the basalts are seen resting on Torridon sandstone with no conglomerate.

It is highly probable that the pebbles in these Rum conglomerates are derived from volcanic agglomerates, representing explosive outbursts in the near vicinity. Special interest thus attaches to the granite pebbles. Throughout the Inner Hebrides the volcanic agglomerates and the conglomerates derived from them consist mainly of basaltic material. With this there may be fragments torn from the underlying sedimentary rocks, as already seen on Canna. These two elements usually make up the whole deposit, excepting only the far-travelled pebbles in some of

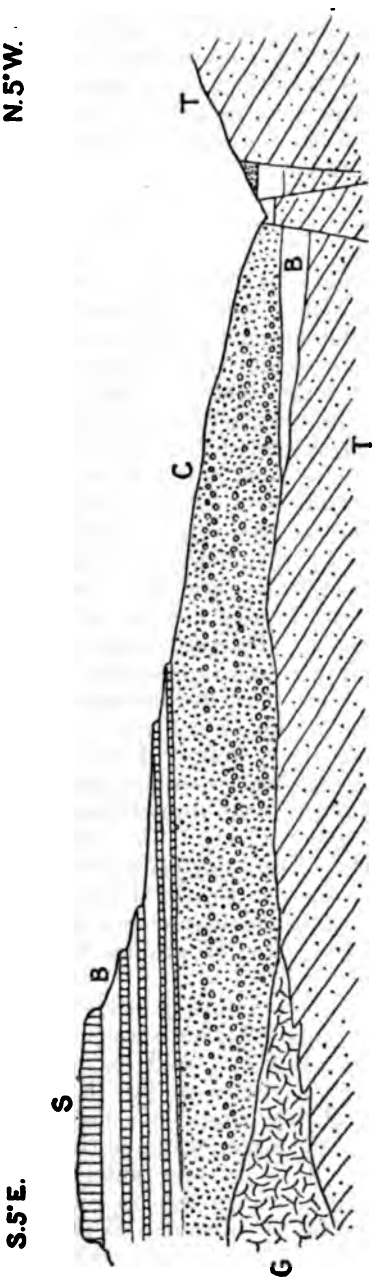

FIG. 14.—Section showing conglomerate in the basalt group, west of Minishal, Rum. Scale, 18 inches to a mile; base-line about 500 feet above sea-level.

T, Torridon sandstone; B, Basaltic lavas; C, Conglomerate; G, Granite; S, Dolerite sills.

the river-conglomerates. In Skye it was found, however, that near the gabbro centre of the Cuillins and the granite centre of the Red Hills a third element enters into the composition of the fragmental accumulations, viz., fragments of plutonic rocks, gabbro and granite, petrographically resembling those which were intruded in the neighbourhood at a later epoch.* It is quite in accordance with this that granite pebbles occur in these Rum conglomerates, near the later granite intrusion of Orval, while they are not found on Canna.

(iii.) EIGG.

Fragmental accumulations in the volcanic series are not largely developed in the Isle of *Eigg*. Tuff occurs under the peat-moss of Blàr Dubh, near Laig, and volcanic agglomerates in two or three other places. The only important occurrences are two which come immediately below the large sheet of pitchstone forming the Sgùrr of Eigg. Their interest arises partly from the fact that Sir Archibald Geikie† has regarded them as river-gravels occupying the bed of an old river, eroded in the basalt group.

The first of the fragmental accumulations referred to is seen in the sea-cliff which cuts off the ridge of the Sgùrr at Bidein Boidheach. The base is perhaps 450 feet above sea-level. It fills a hollow in the basalt group, and has a maximum thickness of about 100 feet, rapidly thinning out in both directions, while the pitchstone rests upon it. This last conjunction can only be an accidental one, for the deposit in question is much older than the pitchstone. It is older than the intrusive sills of dolerite intercalated in the basalt group, one of which, on the south side, may be seen to be stopped and sharply diverted by this massive accumulation. The appearances therefore seem to indicate a volcanic agglomerate, filling a small funnel-like vent, and belonging to the period of the basaltic lavas. The nature of the material is in agreement with this. The principal element is amygdaloidal basalt in pieces up to a foot or two in diameter, subangular or rounded, but fragments of Torridonian origin also occur in some abundance, and there are some of granite and other igneous rock.

The second occurrence has a distinctly bedded arrangement. It is found at the base of the pitchstone escarpment on the south side of the Sgùrr, where it can be traced for forty yards or more. The section at this place is shown in fig. 15. Here we have a breccia or agglomerate of very variable character, containing a large amount of non-volcanic material in addition to amygdaloidal basalt. Torridonian sandstone is very abundant, occurring in angular blocks up to three or four feet in diameter, as well as smaller pieces. White Oolitic sandstone is abundant in places only, and with it occur fragments of brown wood doubtless derived with this sandstone from Jurassic strata in place below. Prof. Seward identifies this wood as *Araucaroxylon*. Distinct from this is a black wood, largely silicified, which is the original *Pinites eiggensis* described many years ago by Witham[*] and by Lindley and Hutton[†]. Pieces of this are scattered in the agglomerate, but the greater part of that which has been discovered has been caught up from the agglomerate by the pitchstone, and is now embedded in the decomposed basal part of the latter rock. Here is a large trunk, about eight feet long, partly broken up and with smaller

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* *Tertiary Igneous Rocks of Skye*, p. 24 (1904).

† *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 303-309 (1871). The arguments against that interpretation have been set forth at length by the present writer, *ibid.*, vol. lxii., pp. 40-67 (1906).

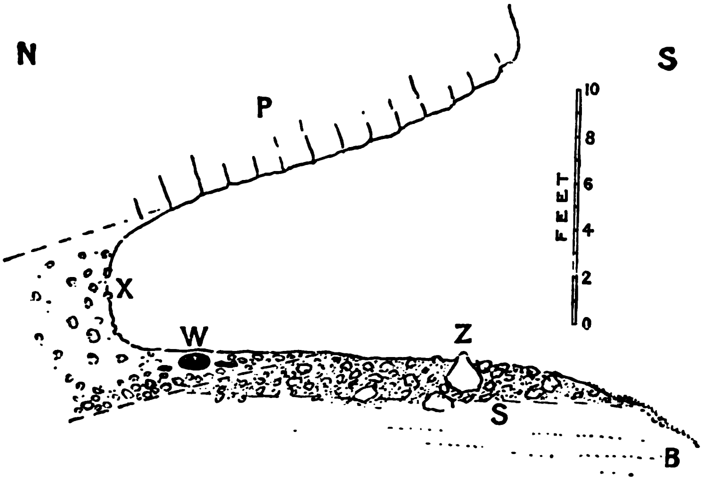

FIG. 15.—Section at the foot of the Sgùrr of Eigg, on the south side. The locality is about a quarter of a mile from the easterly termination of the ridge, and is marked by some small shelters for sheep built in the recess at the base of the pitchstone.

P. Fresh columnar pitchstone forming the roof of a recess or gallery.
X. Brecciated and decomposed basal band of the pitchstone, enclosing some fragments picked up from the rocks below; here about seven feet thick.
W. Large trunk of coniferous wood (*Pinites*), with smaller pieces of the same, enclosed in the decomposed pitchstone.
Z. Volcanic agglomerate, essentially a breccia of basalt, Torridonian rocks, and Oolitic sandstone; contains fossil wood in small pieces: about three feet thick.
S. (exposed about ten yards farther east). Sandstone enclosing fragments of basalt and extraneous rocks as before: about two feet seen. This is the lower part of the same deposit, but differs from Z in having a larger proportion of matrix and in showing a bedded arrangement due to water-action. It contains scattered pieces of wood and a band made up almost wholly of vegetable remains.
B. Basalt lavas below.

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[*] *Observations on Fossil Vegetables*, p. 37 (1831); *The Internal Structure of Fossil Vegetables*, pp. 63-65 (1833).

[†] *The Fossil Flora of Great Britain*, vol. i., pp. 91-92 (1831-3). See also W. Nicol, *Edin. New Phil. Journ.*, vol. xvi., p. 154 (1833); *Rep. Brit. Assoc.* for 1834, Trans. Sections, p. 660 (1835).

pieces lying in the neighbourhood. This fossil pine-wood is for the most part silicified but some only carbonised.

The matrix of the agglomerate, in some places only scantily represented, is partly of basaltic (perhaps ashy) material and partly sandy (probably from the breaking up of the soft Oolitic sandstone), and the binding cement, where such occurs, is calcareous and ferruginous. In the lower part of the deposit, as seen in one place, the enclosed blocks are more sparingly embedded in a matrix of sandstone, which has a distinct bedded character, showing that the finer material of the agglomerate has been rearranged by water-action. Mingled with the enclosed blocks of rock are pieces of black wood, and this further makes a seam of almost pure lignite in the sandstone. This wood is clearly contemporaneous, *i.e.*, of Eocene age. Here, then, we have, interbedded in the basalt group, and some 700 or 800 feet above its base, a deposit a few feet in thickness containing, in addition to basaltic *débris*, much material derived from the underlying foundation of pre-Tertiary strata. With the broken-up Oolitic sandstones occur vegetable remains, which were originally enclosed in those beds. Further, the material of the agglomerate, derived probably from a small vent like that at Bidein Boidheach, has been in some measure sorted by water-action, and has embedded remains of a contemporaneous vegetation.

(iv.) MUCK.

Pyroclastic rocks occur at more than one place on the coast of *Muck*, at or near the base of the basalt group. A considerable thickness is seen on the west side of Camas Mòr, resting directly upon the Oolitic strata (cf. fig. 7, above). The lowest member here is a red laminated and banded tuff, with ferruginous alteration, resembling a variety seen in the Compass Hill section on Canna. A thin basalt flow lies on this, and is succeeded by a volcanic agglomerate, which gives place again in its upper part to red laminated tuff. Then follows the regular succession of basaltic lavas, the whole being, however, complicated by sills of dolerite subsequently intruded. Volcanic agglomerate can be traced for some distance along the coast west of the bay, at and near the high-water mark.

Another locality is the coast at and north of Rudh' a' Chroisein, the headland on the east side of Port Mòr. Here is seen a very hard and tough volcanic agglomerate, weathering with a remarkably rough surface. It is evident that this, too, must be at no great distance above the base of the volcanic series.

CHAPTER VI.

BASALTIC LAVAS AND VOLCANIC FISSURES.

(i.) THE BASALTS AND THEIR PETROGRAPHY.

The distribution of the basic lavas is practically coincident with that already indicated for the volcanic series as a whole. It is very important to observe, however, that where they occur they do not make up the whole of the great piles in which they are displayed. With the flows alternate a great number of intrusive sills, also of basic composition, but belonging to a later epoch. The sills often equal or surpass the lavas in aggregate thickness, and their greater durability gives them the appearance of very marked preponderance. They form all the strong features, in particular the flat surfaces of the plateau-hills and the conspicuous escarpments which terrace the steep slopes; while the lavas are much less prominent, and on peat-covered ground are mostly concealed. The discrimination of these two groups of rocks is fundamental for an understanding of many phenomena in the Tertiary volcanic region. The evidence is based more on comparative mapping than on visible sections, though these, too, are often significant. A summary statement will suffice for the present purpose.

A glance over any landscape on Canna or Eigg (fig. 16), supplemented by the examination of any clear burn-section, tells us that the whole succession is built up by alternations of two different rocks in generally parallel sheets, which range from two or three feet to 100 feet in thickness. The softer rocks, which we term basalts, are usually amygdaloidal and more or less affected by decomposition. They are constantly of fine texture. The strong rocks, which we distinguish as dolerites, are rarely conspicuously amygdaloidal. They are much fresher than the basalts, and, except in the thinnest sheets, are of coarser texture, being visibly crystalline. A well-marked vertical jointing is very general. Thin slices show a difference in microstructure between the two sets of rocks, the augite being usually granulitic in the basalts and ophitic in the dolerites; a difference according well with the supposition that the former are extrusive rocks and the latter intrusive. The individual sheets of dolerite commonly run with remarkable regularity for long distances; but in places they are seen to shift their horizon among the basalts, to come together, or to separate. More marked irregularities occur where a dolerite encounters a thick mass of coarse agglomerate or conglomerate, and the sheet may even come to an abrupt end (fig. 12). The dolerites occasionally enclose abundant fragments of the amygdaloidal basalts; and in a few cases it can be verified that a dyke cutting the basalts is itself cut by a dolerite sheet. The dolerites are not confined to the volcanic series. but are found with identical characters in the subjacent Jurassic strata of Eigg and Skye, where their intrusive nature is beyond doubt. Especially noteworthy is it that among the basalt fragments of the volcanic agglomerates and conglomerates we find no pieces of the more durable dolerites. Again, in Skye the dolerite sills die out as they approach the border of the mountains, where the basalt lavas are metamorphosed by the plutonic intrusions and have lost their bedded character. The large patches of volcanic rocks enclosed in the gabbro and granite have no dolerite associated with them. This may be seen on Orval, in Rum, while the dying-out of the dolerites at the belt of metamorphism is well shown near the gabbro of the Isle of Muck (fig. 27a). From these various considerations it appears clearly that the dolerites are not only intrusive, but represent intrusions of post-plutonic date. The description of them is accordingly deferred to a later chapter.

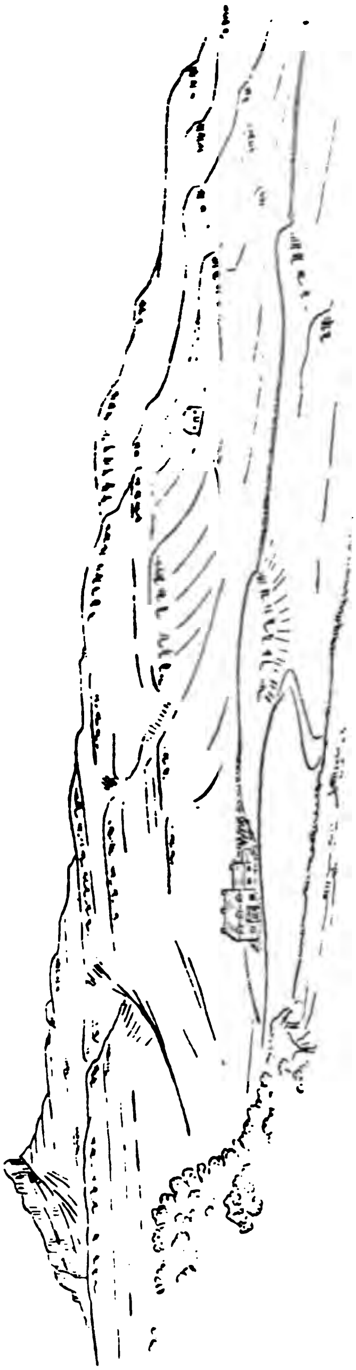

FIG. 16.—Outlines of hills on Eigg, seen from Galmisdale. The strong escarpments are made by dolerite sills intruded in the basalt group. The pitchstone ridge of the Sgùrr is seen to the left.

The basic lavas of the Small Isles are, in the freshest examples, black close-grained rocks, usually without any conspicuously larger crystals. The commoner varieties have a dull appearance and greenish-grey, reddish-brown, or other colours, depending on the kind and degree of partial alteration. An amygdaloidal structure is very general, the vesicles being filled with white zeolites, greenish-black chloritic minerals, or other secondary substances.

To illustrate the *chemical composition* of these rocks, Dr. Pollard has made a complete analysis of an example from the north-eastern shoulder of Orval, in Rum. This was selected for its freshness, due partly to its non-amygdaloidal character, partly to a certain degree of metamorphism by the neighbouring granite. It has a rather more evidently crystalline texture than most of the lavas, and consists of labradorite, augite, olivine, opaque iron-ore, and apatite. The analysis is given in Column I., and beside it, for comparison, the analysis of a rock of the same group from Skye (Column A.). The agreement between the two is very marked. The Rum lava is rather richer in iron and manganese oxides,

	I.	A.
SiO_2	46·46	46·61
TiO_2	2·07	1·81
Al_2O_3	15·48	15·18
Cr_2O_3	0·02	0·04
V_2O_3	0·05	0·04
Fe_2O_3	3·63	3·49
FeO	10·23	7·71
NiO, CoO	0·02	trace.
MnO	0·48	0·13
MgO	6·80	8·66
CaO	9·05	10·08
BaO	0·02	not det.
SrO	trace?	not det.
Na_2O	3·01	2·43
K_2O	0·68	0·67
Li_2O	trace?	not det.
H_2O above 105°	1·43	2·07
at 105° C.	0·89	1·10
CO_2	—	trace.
P_2O_5	0·30	0·10
$\frac{1}{2}S$	0·08	—
	100·70	100·12

I. [11,727].—Olivine-Basalt, lava, north-east shoulder of Orval, Rum: anal. W. Pollard.

A. [8185].—Olivine-Basalt, lava, near bridge over Allt Fionnfhuachd, Drynoch, Skye: anal. W. Pollard, *Tertiary Igneous Rocks of Skye* (1904), pp. 31, 249.

titanic acid, and soda, and poorer in magnesia and lime. We may infer that it contains a little more iron-ore than the Skye rock, with a more ferriferous augite and a more sodic variety of labradorite: it has also more apatite.

The basalt lavas of the Small Isles in general consist of the minerals already named, except that olivine is frequently wanting, or at least has left no certain trace in the often much-decomposed rock. The presence or absence of this mineral does not seem to import any considerable difference in the general nature of the rocks, and all those studied are of basaltic rather than andesitic affinities, though the range of variety may be greater than that actually verified. The relative proportions of felspar, augite, and magnetite vary in different examples. In the ordinary fine-textured basalts the little elongated felspars, with twin-lamellæ, are often about ·005 inch long. Sometimes there are scattered crystals of rather large size (·02 inch or more), but a conspicuous porphyritic structure, with crystals of half an inch or more, is quite exceptional: it is seen in the basal flow on Muck. Relatively coarse-textured basalts, with felspars up to ·03 inch long, are also of exceptional occurrence, the analysed rock from Orval being an example. The pale-brown augite is commonly in the form of little granules wedged between the felspar crystals, though sometimes it has a sub-ophitic habit. The olivine, when present, builds rather rounded crystal grains. The black iron-ore is in microscopic crystals with more or less of the regular octahedral shape, and is presumably titano-magnetite, no ilmenite being distinguishable. Apatite, in slender needles, has a somewhat capricious distribution.

The majority of the rocks are much altered, and this is especially noticeable in the highly amygdaloidal varieties, which are everywhere the most common. Chloritic minerals, calcite, and zeolites, with allied hydrous compounds, figure most prominently among the secondary products; and in many cases also there is a copious separation of ferruginous material, chiefly limonite or sometimes hæmatite. The finer-textured rocks are usually so much obscured by alteration that it is difficult to pronounce concerning the possible presence of a glass residue; but the greater part of the lavas, at least, have been holocrystalline.

The contents of the *amygdaloidal* and *geodic cavities* in the basalts are various. The most usual are zeolites, which occur in rich variety, two or three species being often associated in the same cavity. The larger spaces are not entirely filled, and here the crystals may assume very perfect forms. Good localities for collecting are along the south coast of Canna (west of the harbour) and in the neighbourhood of Uamh Fhraing, the well-known cave on the south coast of Eigg. The commonest species are analcime, chabasite, stilbite, and especially radiate fibrous forms which are probably for the most part mesolite, though thomsonite and perhaps others occur. Heddle records faroëlite from Eigg, heulandite and laumontite from Canna, and uigite from Eilean nan Each, Muck. These are all lime- and lime-soda-zeolites, excepting analcime, which is possibly also a lime-bearing variety. They are doubtless derived in a very direct way from the lime-soda-felspars of the basalts. It is probable that they were formed, with the aid of volcanic water, while the rocks were still at somewhat high temperatures, and that the process was quite different from anything properly termed "weathering."

In addition to the zeolite family, gyrolite and apophyllite are found. Calcite sometimes accompanies zeolites, or it may occur alone, or less commonly with quartz. In some places the amygdaloidal cavities contain members of the chlorite group, the identification of which is not always practicable. On Umaolo, an isolated rock between Canna and Oigh-sgeir, Heddle remarked amber-coloured saponite, presumably in vesicles of the basalts; while chlorophæite occurs on Canna and probably elsewhere. More commonly the chloritic minerals of these rocks have neither the bright green colour of saponite nor the lustrous brownish-black of chlorophæite, but have a dull greenish-black appearance. The green colour is more evident where the mineral is disseminated through some colourless substance, such as calcite or chalcedony. The vesicles are often filled in this way, with a dark purely chloritic border. The latter shows a general radiate arrangement, and the disseminated green material consists of fine scales collected in radiate fashion to form little pellets.

Atmospheric weathering, as distinguished from the processes connected with the infilling of the vesicles, has affected some of the basalts in a very noteworthy degree. This kind of alteration is found especially at the upper surface of a flow, and there can be no doubt that it was effected before the flow was covered by the next succeeding one. The ultimate result is a *red siliceous clay*, consisting essentially of hydrated aluminium silicate and ferric oxide. Bands of this brick-red clay ("plinthite"),* having a thickness of a few inches, are not uncommon. Good examples may be seen between Kildonan and the Manse, on Eigg; by the roadside three-quarters of a mile east of Gallanach, on Muck; on Castle Island; and in many other places.

The bands of decayed basalt, approximating more or less to the condition of soft clay, have afforded easy passage to the subsequent intrusions of dolerite sills; and the general regularity with which the sills are interposed between the successive flows of basalt depends largely upon this regular recurrence of these parallel surfaces of weakness. It is very noticeable that the conspicuous bands of "plinthite" clay are usually found immediately below strong sills of dolerite. This conjunction might suggest that the peculiar character of these weathered crusts on the basalts is connected with the dolerite intrusions, but similar bands of red clay are found where no intrusion occurs. The clays show no noticeable induration in contact with the dolerites, and indeed it is rather a striking feature of the basic sills of this region that their intrusion has rarely been attended by any important metamorphic effects.

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* For analysis of similar material from Skye see *Tertiary Igneous Rocks of Skye*, p. 48 (1904).

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Regarding the basaltic lavas of this region as the result of an extensive system of fissure-eruptions, we should expect the fissures of supply to be represented by *dykes*, and it would be of interest to identify some of these dykes. It is, however, a task of much difficulty to decide which among the many basic dykes met with are to be referred to this early epoch. We may seek them especially in districts, such as the northern parts of Rum, where the volcanic rocks have been stripped away, exposing the pre-Tertiary strata; but, unfortunately, in such places data are usually wanting for discriminating the various basic dykes according to their ages. That some, though doubtless a minor proportion, of the basic dykes do belong to the volcanic phase is nevertheless demonstrable. In several localities in the Isle of Rum basic dykes are found entangled, in a highly metamorphosed condition, in the plutonic rock-masses. One is enclosed in one of the smaller granite intrusions at Inbhir Ciell, in the southern part of the island. Others are seen entangled in gneiss and granite to the north-east of Loch Sgathaig. It is probable that the pre-plutonic group of dykes, to which these and other examples belong, may represent the feeders of the basaltic lavas. Certain other dyke-intrusions, which may be of like age and relationship, will be noticed with more particularity.

The Tertiary basic dykes of the British area do not often occur in fault-lines, or with any other obvious relation to geological accidents, their positions and directions being in general determined by some larger law. Thus, in Skye, where many thousands

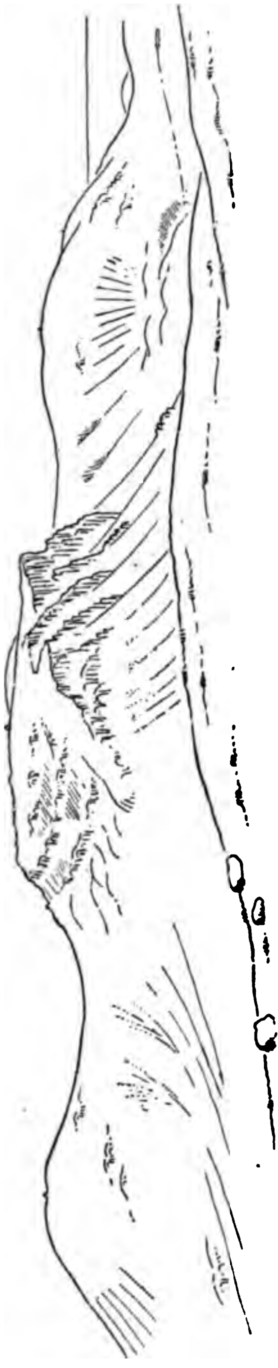

FIG. 17.—Outlines of Orval, seen from Fionn-Chrò, Rum. An outlier of metamorphosed basalt makes prominent crags, contrasting with the smooth outline of the granite hills.

of dykes were examined in the course of the survey, comparatively few cases were observed in which they had been intruded along lines of faulting or crushing, or, on encountering such breaches of continuity, had followed them for some distance.* A like independence of geological accidents characterises the ordinary basic dykes in Rum. There is, however, a special group of intrusions constantly associated with *vertical bands of fracture and crushing;* and with these actual intrusions must be included other occurrences in which similar peculiarities are found although no igneous intrusion can be verified. The attendant circumstances are sufficiently remarkable to merit detailed examination.

More than twenty cases have been noted in one limited area of Torridonian sandstone in the northern part of Rum. Several are found within a distance of about two miles to the south-west of Kilmory, and the rest are scattered along a belt of ground extending from there towards Loch Scresort. There is in each case, cutting sharply across the undisturbed sandstones, a vertical band which gives evidence, firstly, of mechanical effects, often amounting to thorough brecciation, and, secondly, of thermal effects, which may or may not involve an actual injection of igneous magma. There is no displacement of the nature of faulting, and the bands themselves are traceable only for short distances. Where igneous rock is present, it is of a peculiar nature, but, as will be seen, it may be regarded as a modified basalt.

The thermal effects observable in these crush - bands may, without fear of error, be referred to a Tertiary date, since no earlier igneous action is known in the island. It is conceivable that these effects may have been guided by lines of fracture and crushing initiated at a much earlier epoch, but there is nothing to support this supposition. Local brecciation doubtless referable to the great Palæozoic system of disturbances is not infrequent in the same area; but this invariably follows gently inclined or nearly horizontal surfaces, which may be regarded as incipient overthrusts. The vertical crush-bands now in question seem to have a different significance, being rather the analogues of normal faults. In direction they agree generally, though not in every case precisely, with the Tertiary dykes of the area. Moreover, two of the injected crush-bands intersect the overthrust mass of crush-conglomerate on Monadh Dubh, and it is there very evident that they represent a distinct and later set of disturbances. We may therefore infer with some probability that the crushing along vertical lines, no less than the igneous injection and other effects which followed it, belongs to a Tertiary date.

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* *Tertiary Igneous Rocks of Skye,* p. 302.

Considering the several occurrences, we find considerable differences in the appearances which they present; but the varieties graduate into one another, and may be seen along different parts of one and the same line. Especially striking is the evidence of marked thermal metamorphism in many places where no igneous rock is to be detected. The effects differ in degree. In one or two cases we can observe nothing more definite than the bleaching which is invariably the first result of thermal metamorphism in the red Torridonian sandstones. More often the metamorphism is of a high grade, fully comparable with what is seen elsewhere in Rum, where the sandstones are in contact with large plutonic intrusions. The altered rock often shows the quasi-spherulitic appearance due to a stellate disposition of the recrystallised felspar. It is invariably to be observed that all metamorphic effects are strictly confined to the crush-band itself, which is thus sharply marked off from the undisturbed and unaltered red sandstone which borders it. Even from a distance the pale band traversing the bright red sandstone is often a conspicuous object.

As a rule, the mechanical effects of crushing are apparent in a brecciation of the sandstone within the limits of the band; but this is not quite universal, and it does not always affect the whole of the band equally. In the lower part of a burn, about 700 yards west of Kilmory Lodge, is a sharply defined line running north-west–south-east, along which bleaching of the red sandstone is the only apparent effect, and there are other cases where the mechanical effects of crushing are, along some part of the line at least, not very strongly marked. As a rule, brecciation is evident, affecting the whole width of the crush-band and ceasing abruptly at its walls. In some instances the friction has been such as to give the sandstone fragments rounded shapes. The crush-bands marked B, C, D, E on the accompanying sketch-map (fig. 18) are distinguished by more or less pronounced brecciation with bleaching and other signs of metamorphism, but without any visible

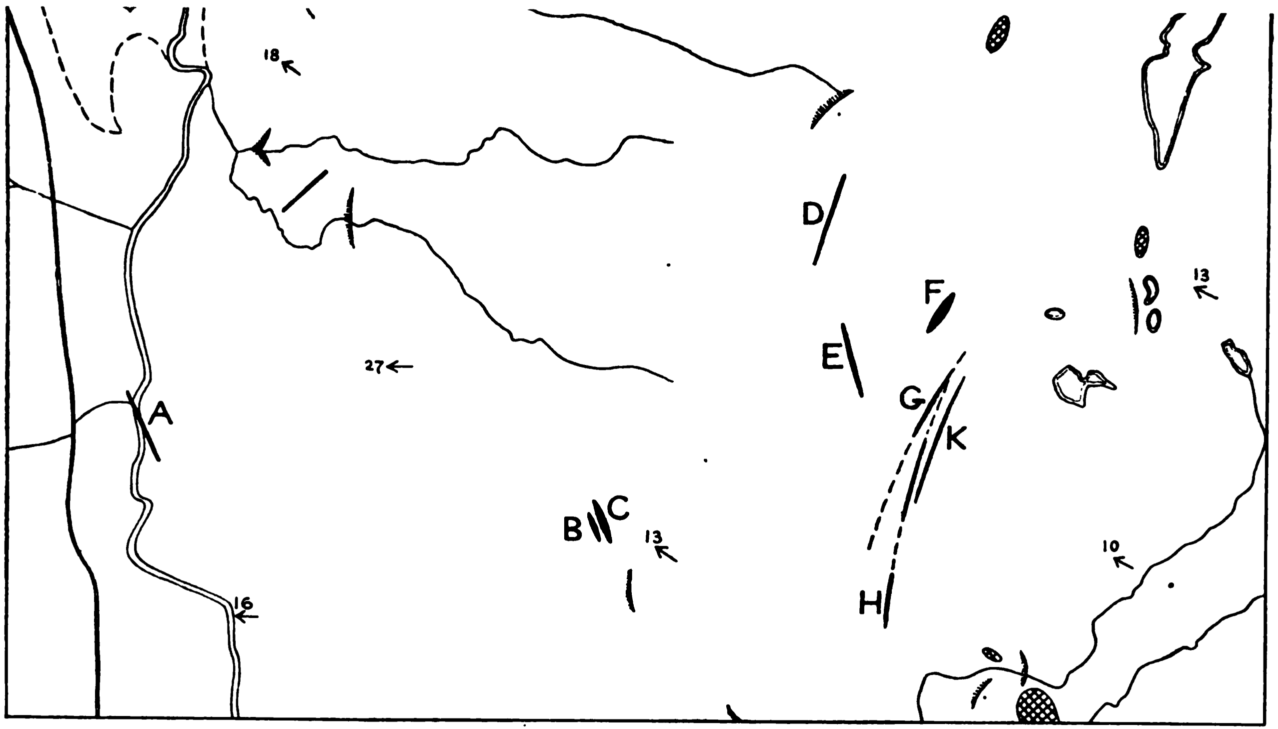

FIG. 18.—Sketch-map of a small area on the hills east of Kilmory Glen, in the Isle of Rum, to show the situations of some of the metamorphosed and injected crush-bands. Scale, 6 inches to a mile.

The several occurrences are distinguished by letters and referred to in the text. There are also shown certain sheets of basalt (shaded) and some small intrusions of gabbro or eucrite (cross-hatched).

igneous rock. Other examples occur in the neighbourhood of Guirdil.

In the majority of cases there has been some intrusion of an igneous magma, probably of basaltic composition; but even here it does not always affect the full width or the entire length of the metamorphosed crush-band. At F (fig. 18) is a crush-band which reaches a maximum width of 50 feet, though, as is usually the case, it soon dies out in the direction of its length. The brecciated rock is highly metamorphosed, but only on the western margin has there been an actual injection of the basalt magma. A more characteristic example is the bifurcating band G, H, which can be traced for a quarter of a mile with a width usually two to six feet. In some parts of the length the metamorphism is not related to any visible igneous rock; but in other parts there has been intrusion. giving a kind of breccia or conglomerate with fragments of metamorphosed sandstone in a matrix of igneous origin. According to the relative proportions of fragments and matrix, we may regard this as a crush-conglomerate injected with basalt or as a basalt dyke crowded with xenoliths of sandstone. Even here there is sometimes a portion of the width of crush-band free from igneous intrusion. Similar phenomena may be seen in an injected crush-band, 15 feet wide, crossing the Kilmory River at the place marked A on the map. Here again the relative proportions of the crushed and metamorphosed sandstone and the igneous rock are variable. We may note a few other examples. A six-feet dyke full of sandstone fragments is seen on the slope west of Kilmory Glen, about 400 yards south-west of the old burying-ground. A crush-band much injected with basaltic magma crosses the footpath in Glen Seilisdeir, nearly a mile west of Kilmory Glen. Two are seen cutting the mass of overthrust crush-breccia on Monadh Dubh, and another a little to the north-east. One occurs a little south of the largest tarn on Mullach Mòr, and another about 670 yards east of the same tarn. The most easterly example noted is seen to the south-west of Loch Mitchell and nearly 1400 yards north-west by north of Kinloch Castle. The most easily accessible occurrence is cut by the road up Glen Kinloch, about 30 or 40 yards before the fork of the road; but the relations of this are not exposed.

In every case where a crush-band has been invaded by igneous magma there have been important *chemical reactions* between this and the sandstone, in so much that the rock formed by consolidation of the fused mass is one of peculiar petrographical characters. So general is this modification of the intruded magma that we have no direct indication of its precise original composition; but it is not necessary to suppose that it differed materially from that of ordinary basic dykes in the district. The difference now observable may be attributed to the fusion and incorporation in the molten magma of part of the sandstone with which it came in contact. The sandstone consists essentially of quartz and fresh alkali-felspar, and the result of its incorporation in the magma would be an enrichment of the latter in silica and alkalies. A modification of this kind affecting a normal basaltic magma seems to account sufficiently for the unusual constitution of the rock as observed. It is of grey colour, notably lighter than the ordinary basalt dykes, and of fine texture. Thin slices show that the mass is composed mainly of slender felspar crystals with quite low extinction-angles. It is probable that orthoclase is present as well as one of the more acid varieties of plagioclase. There is a strong tendency to radiate and fan-like grouping (fig. 19.) The most usual ferro-magnesian element of the rock is represented by numerous little pale-green or yellow serpentinous pseudomorphs, which seem to replace a rhombic pyroxene. Granules of epidote are also found. The radiate grouping of relatively acid felspar-fibres and the occurrence of a rhombic pyroxene instead of augite are characteristic features in other cases of acidified basic rocks; *e.g.*, in a large dyke full of quartz-pebbles and *débris* which crosses the ridge of Blath-bheinn, in Skye.* In the slices abundant sand-grains in a partly corroded state are seen embedded in an igneous matrix having the characters described. The intimate admixture of the two rocks involved is seen, on a somewhat larger scale, in hand-specimens, and it is probable that the general rounded form of the sandstone xenoliths is due in considerable degree to the corrosion which they have suffered.

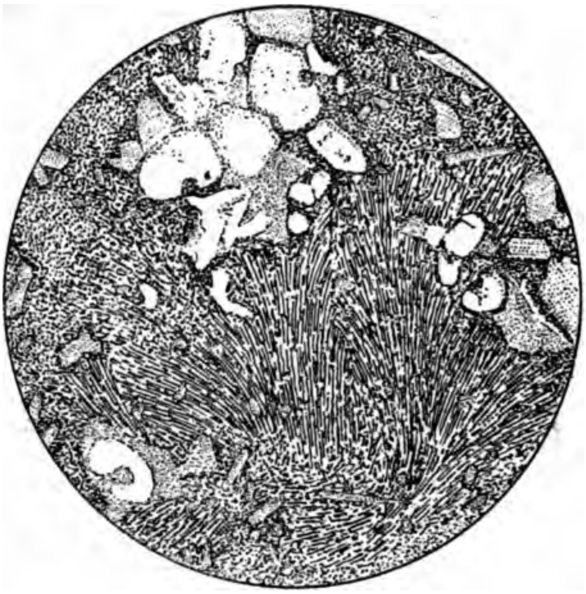

FIG. 19 [10,486].—Basalt modified by absorbing sandstone material, in injected crush-band on slope west of Loch an Tairbh, near Kilmory, Rum ; × 30.

The felspar fibres which make the principal element have a radiate or plumose arrangement. Embedded in the mass are corroded grains of quartz and serpentinous pseudomorphs after a rhombic pyroxene.

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* *Tertiary Igneous Rocks of Skye*, pp. 352, 353, and pl. xxiv., fig. 4.

CHAPTER VII.

PLUTONIC ROCKS: ULTRABASIC GROUP.

I. THREE GROUPS OF PLUTONIC INTRUSIONS.

The Tertiary plutonic rocks of Rum make up most of the southern half of the island, occupying an area which we may estimate roughly as about 19 square miles. This is divided as follows:—

	Sq. miles.
i. Peridotite and other ultrabasic rocks, about -	9½
ii. Eucrite and Gabbro - - - - -	3½
iii. Granite (including granophyre) and Gneiss	6

The average elevation of the ground is greater than in the Torridonian tract to the north, and most of the principal summits of Rum are built up of the plutonic rocks, especially the ultrabasic group. We shall call them mountains by right of the bold relief which they present, although their actual height is not great, the highest summit, Askival, rising only 2659 feet above the sea.

The three groups of plutonic rocks were intruded in the order in which we have named them. The several intrusions have assumed for the most part a sheet-form or laccolitic habit, with an inclination usually at no great angle from the horizontal. This disposition is, however, not maintained in all parts of the area. It is most evident in the eastern half, where the several members of the ultrabasic group and the eucrites below exhibit a regularity comparable with that of stratified formations. Farther west there are considerable departures from this regular arrangement, and the junctions are sometimes inclined at high angles. Along parts of the northern border, in the central portion of the island, the peridotites and eucrites are seen to cut almost vertically through the highly disturbed Torridonian strata; and a like relation holds for most of the small outlying intrusions of the same rocks, which are scattered through the tract of sandstone to the north.

Despite these exceptions, we may regard the several groups of plutonic rocks as having roughly the form of large laccolitic bodies. In so far as this holds good, we may further remark that, in the [illegible] of the several groups, the younger has been intruded [illegible] the older, in contact with it and in places invading it. [illegible]basic rocks occupy the highest position, and in consequence show a somewhat greater predominance on the map than that to which their relative bulk would entitle them. The eucrite and gabbro appear as an irregular belt, surrounding the former group, and scarcely broken except by the sea on the south-west side. The acid rocks, making a considerable spread in the west, pass obliquely under the eucrite; and when they reappear near Papadil, in the south, they are again found to be intruded below the older plutonic masses.

Where the prevalent stratiform disposition of the rocks breaks down, the younger group may be found to burst transgressively through the older. In this way the eucrite and gabbro break through the peridotite group to the west of Trallval, and the acid rocks come to light in Fiadh-innis. The junctions between the several groups are in some places of a highly intricate nature, such as can be rendered only conventionally even on a large-scale map. The newer rock has sometimes penetrated the older in a network of ramifying veins; and has enclosed detached blocks of it, of all sizes, also intimately veined. The junction is thus not a line but a zone, which may have a width of a hundred yards or more. Such a zone of mechanical admixture may be termed for convenience an *intrusion-breccia.* It is found not only between the ultrabasic and the basic group, but also with remarkable development between different members of the former. In such cases there has been no noticeable chemical reaction between the twe rocks involved. Very different is the case where the invading magma was an acid one. In several parts of Rum mutual reactions between eucrite and granite have given rise to a remarkable set of mixed and hybrid rocks; and, in conjunction with contemporaneous crust-movements, have produced a group of gneisses.

In most of the foregoing particulars the plutonic rocks of Rum present a very close parallel to those of Skye. In the latter island we find also three groups, corresponding with those recognised above, though not petrographically identical; and they were intruded also in the same order, viz., the order of decreasing basicity. The same laccolitic habit characterises the larger intrusions, and the granite of the Red Hills passes under the gabbro of the Cuillins. A typical intrusion-breccia between peridotite and gabbro is seen in the neighbourhood of Loch Scavaig; and on Marsco and elsewhere the gabbro and granite have entered into remarkably intimate relations, giving rise to hybrid rocks, though not in this case to gneisses.

(ii.) GEOLOGICAL RELATIONS OF THE ULTRABASIC (PERIDOTITE-ALLIVALITE) GROUP.

The ultrabasic group builds most of the higher ground in the southern half of Rum. It makes Barkeval, Allival, Askival, and Trallval, and extends north-westward to near the head of Kilmory Glen, westward to the longitude of Harris, and south-westward to form the rugged ridge of Ruinseval and most of the precipitous coast between Harris and Papadil (fig. 20). This continuous

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Regarding the basaltic lavas of this region as the result of an extensive system of fissure-eruptions, we should expect the fissures of supply to be represented by *dykes*, and it would be of interest to identify some of these dykes. It is, however, a task of much difficulty to decide which among the many basic dykes met with are to be referred to this early epoch. We may seek them especially in districts, such as the northern parts of Rum, where the volcanic rocks have been stripped away, exposing the pre-Tertiary strata; but, unfortunately, in such places data are usually wanting for discriminating the various basic dykes according to their ages. That some, though doubtless a minor proportion, of the basic dykes do belong to the volcanic phase is nevertheless demonstrable. In several localities in the Isle of Rum basic dykes are found entangled, in a highly metamorphosed condition, in the plutonic rock-masses. One is enclosed in one of the smaller granite intrusions at Inbhir Ciell, in the southern part of the island. Others are seen entangled in gneiss and granite to the north-east of Loch Sgathaig. It is probable that the pre-plutonic group of dykes, to which these and other examples belong, may represent the feeders of the basaltic lavas. Certain other dyke-intrusions, which may be of like age and relationship, will be noticed with more particularity.

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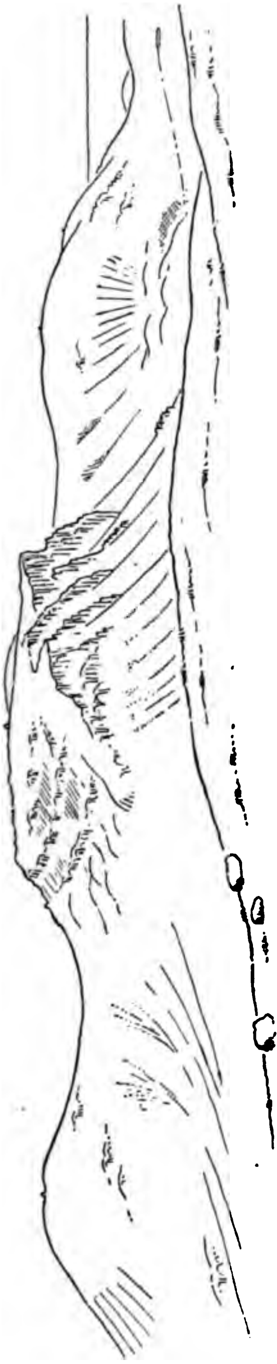

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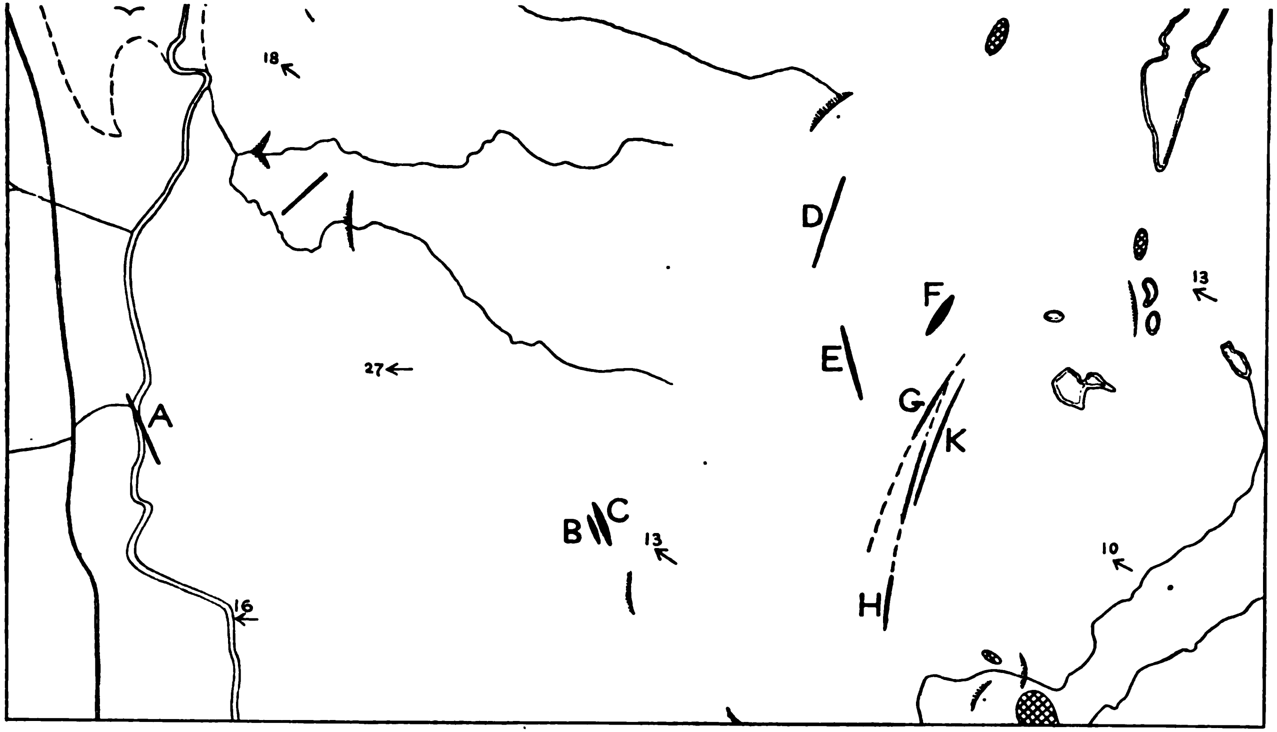

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The several occurrences are distinguished by letters and referred to in the text. There are also shown certain sheets of basalt (shaded) and some small intrusions of gabbro or eucrite (cross-hatched).

igneous rock. Other examples occur in the neighbourhood of Guirdil.

In the majority of cases there has been some intrusion of an igneous magma, probably of basaltic composition; but even here it does not always affect the full width or the entire length of the metamorphosed crush-band. At F (fig. 18) is a crush-band which reaches a maximum width of 50 feet, though, as is usually the case, it soon dies out in the direction of its length. The brecciated rock is highly metamorphosed, but only on the western margin has there been an actual injection of the basalt magma. A more characteristic example is the bifurcating band G, H, which can be traced for a quarter of a mile with a width usually two to six feet. In some parts of the length the metamorphism is not related to any visible igneous rock; but in other parts there has been intrusion, giving a kind of breccia or conglomerate with fragments of metamorphosed sandstone in a matrix of igneous origin. According to the relative proportions of fragments and matrix, we may regard this as a crush-conglomerate injected with basalt or as a basalt dyke crowded with xenoliths of sandstone. Even here there is sometimes a portion of the width of crush-band free from igneous intrusion. Similar phenomena may be seen in an injected crush-band, 15 feet wide, crossing the Kilmory River at the place marked A on the map. Here again the relative proportions of the crushed and metamorphosed sandstone and the igneous rock are variable. We may note a few other examples. A six-feet dyke full of sandstone fragments is seen on the slope west of Kilmory Glen, about 400 yards south-west of the old burying-ground. A crush-band much injected with basaltic magma crosses the footpath in Glen Seilisdeir, nearly a mile west of Kilmory Glen. Two are seen cutting the mass of overthrust crush-breccia on Monadh Dubh, and another a little to the north-east. One occurs a little south of the largest tarn on Mullach Mòr, and another about 670 yards east of the same tarn. The most easterly example noted is seen to the south-west of Loch Mitchell and nearly 1400 yards north-west by north of Kinloch Castle. The most easily accessible occurrence is cut by the road up Glen Kinloch, about 30 or 40 yards before the fork of the road; but the relations of this are not exposed.

In every case where a crush-band has been invaded by igneous magma there have been important *chemical reactions* between this and the sandstone, in so much that the rock formed by consolidation of the fused mass is one of peculiar petrographical characters. So general is this modification of the intruded magma that we have no direct indication of its precise original composition; but it is not necessary to suppose that it differed materially from that of ordinary basic dykes in the district. The difference now observable may be attributed to the fusion and incorporation in the molten magma of part of the sandstone with which it came in contact. The sandstone consists essentially of quartz and fresh alkali-felspar, and the result of its incorporation in the magma would be an enrichment of the latter in silica and alkalies. A modification of this kind affecting a normal basaltic magma seems to account sufficiently for the unusual constitution of the rock as observed. It is of grey colour, notably lighter than the ordinary basalt dykes, and of fine texture. Thin slices show that the mass is composed mainly of slender felspar crystals with quite low extinction-angles. It is probable that orthoclase is present as well as one of the more acid varieties of plagioclase. There is a strong tendency to radiate and fan-like grouping (fig. 19.) The most usual ferro-magnesian element of the rock is represented by numerous little pale-green or yellow serpentinous pseudomorphs, which seem to replace a rhombic pyroxene. Granules of epidote are also found. The radiate grouping of relatively acid felspar-fibres and the occurrence of a rhombic pyroxene instead of augite are characteristic features in other cases of acidified basic rocks; *e.g.*, in a large dyke full of quartz-pebbles and *débris* which crosses the ridge of Blath-bheinn, in Skye.* In the slices abundant sand-grains in a partly corroded state are seen embedded in an igneous matrix having the characters described. The intimate admixture of the two rocks involved is seen, on a somewhat larger scale, in hand-specimens, and it is probable that the general rounded form of the sandstone xenoliths is due in considerable degree to the corrosion which they have suffered.

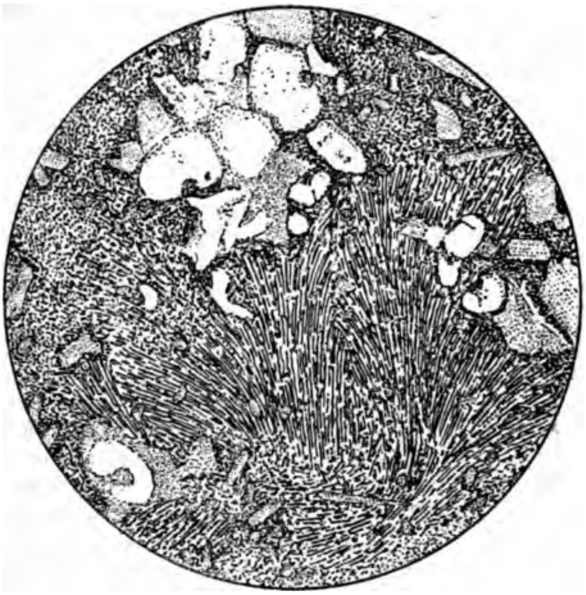

FIG. 19 [10,486].—Basalt modified by absorbing sandstone material, in injected crush-band on slope west of Loch an Tairbh, near Kilmory, Rum ; × 30.

The felspar fibres which make the principal element have a radiate or plumose arrangement. Embedded in the mass are corroded grains of quartz and serpentinous pseudomorphs after a rhombic pyroxene.

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* *Tertiary Igneous Rocks of Skye*, pp. 352, 353, and pl. xxiv., fig. 4.

The peculiar phenomena connected with these metamorphosed and injected crush-bands raise some difficult geological questions. Especially interesting is the very clear evidence of metamorphism, incontestably of the thermal type, where no igneous rock is found. It might be suggested that, where such metamorphism is verified, without visible intrusion, the igneous rock is situated only a short distance below, the case being thus one of the upward termination of a dyke, such as may occasionally be observed among our Tertiary igneous rocks. Having regard, however, to the various altitudes of the occurrences, such a hypothesis is seen to be a very artificial and inconclusive one. It is not easy to believe that the present hilly surface of the ground chances to coincide so nearly with the varying upward limit of a set of basaltic injections. We have also to take into account the high grade of metamorphism indicated in many of these cases and its remarkably narrow restriction, leaving the red sandstone which borders the crush-band wholly unchanged. These considerations rather suggest that, under certain conditions, notable metamorphism may be brought about by some kind of *solfataric agency*, operating along vertical bands of rock disintegrated by crushing. If this be an admissible supposition, the injection of the basaltic magma, or its absence, may be an incident of secondary importance with reference to the metamorphic effects. The profound mutual reactions between the magma, where it has found entrance, and the contiguous sandstone afford some confirmation of the supposition that it was preceded by the passage of heated vapours. The melting of so considerable an amount of sandstone, assumed cold, would imply a remarkable degree of superheating in the magma as intruded; and this adds weight to the alternative supposition that the brecciated sandstone in the crush-band had already been raised to a high temperature prior to the intrusion of the basalt magma.

The peculiar features described serve to connect together the various occurrences, ranging from a mere bleached line of fracture in the red sandstone to a dyke full of sandstone *débris*. Distinct from the ordinary basalt dykes, which very seldom enclose sandstone fragments, though they occasionally carry xenoliths of plutonic rocks, these metamorphosed and injected crush-bands constitute a group apart, and must be referred to some special phase in the evolution of Tertiary igneous activity in the region. If we enquire to what epoch in the sequence of events this group belongs, we find but little positive evidence bearing on the question, and any attempt to answer it must partake largely of the nature of conjecture. No instance has been observed of a crush-band of this kind traversing any igneous rock, and but one or two doubtful cases of ordinary basalt dykes cutting a crush-band. The fact that all the occurrences are situated in pre-Tertiary rocks, which have once been overlain by the volcanic group, is consistent with an early Tertiary date, falling within the volcanic phase. The apparent indications of solfataric action point to the same conclusion, for the amygdaloidal lavas afford abundant evidence of the agency of heated vapours at that stage. In their sub-parallel arrangement, short extent, and somewhat irregular course these lines of fracture suggest a comparison with the fissures which fed the basaltic lava-flows. Certain other features are also suggestive in this connection. In some parts of Skye, where the removal of the lavas has exposed Torridonian sandstones on which these have rested, the sandstone is found to be very intimately involved with basalt in what are probably channels of supply of the basic lavas; and in the vicinity sandstone fragments are found in the basal portion of the lavas themselves.*

It seems possible that the peculiar metamorphosed and injected crush-bands of Rum represent what were, in the volcanic period, fissures communicating with the outer air, and that they may be regarded as incipient or aborted channels for the fissure-eruptions of basic lava.

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* *Tertiary Igneous Rocks of Skye*, pp. 13, 40.

CHAPTER VII.

PLUTONIC ROCKS: ULTRABASIC (RUM).

(i.) THREE GROUPS OF PLUTONIC INTRUSIONS.

The Tertiary plutonic rocks of Rum make up most of the southern half of the island, occupying an area which we may estimate roughly as about 19 square miles. This is divided as follows:—

	Sq. miles.
(i.) Peridotite and other ultrabasic rocks, about -	9½
(ii.) Eucrite and Gabbro, - - - - - -	3½
(iii.) Granite (including granophyre) and Gneiss,	6

The average elevation of the ground is greater than in the Torridonian tract to the north, and most of the principal summits of Rum are built by the plutonic rocks, especially the ultrabasic group. We shall call them mountains by right of the bold relief which they present, although their actual height is not great, the highest summit, Askival, rising only 2659 feet above the sea.

The three groups of plutonic rocks were intruded in the order in which we have named them. The several intrusions have assumed for the most part a *stratiform* or *laccolitic habit*, with an inclination usually at no great angle from the horizontal. This disposition is, however, not maintained in all parts of the area. It is most evident in the eastern half, where the several members of the ultrabasic group and the eucrites below exhibit a regularity comparable with that of stratified formations. Farther west there are considerable departures from this regular arrangement, and the junctions are sometimes inclined at high angles. Along parts of the northern border, in the central portion of the island, the peridotites and eucrites are seen to cut almost vertically through the highly disturbed Torridonian strata; and a like relation holds for most of the small outlying intrusions of the same rocks, which are scattered through the tract of sandstone to the north.

Despite these exceptions, we may regard the several groups of plutonic rocks as having roughly the form of large laccolitic bodies. In so far as this holds good, we may further remark that, in the sequence of the several groups, the younger has been intruded beneath the older, in contact with it and in places invading it. The ultrabasic rocks occupy the highest position, and in consequence show a somewhat greater predominance on the map than that to which their relative bulk would entitle them. The eucrite and gabbro appear as an irregular belt, surrounding the former group, and scarcely broken except by the sea on the south-west side. The acid rocks, making a considerable spread in the west, pass obliquely under the eucrite; and when they reappear near Papadil, in the south, they are again found to be intruded below the older plutonic masses.

Where the prevalent stratiform disposition of the rocks breaks down, the younger group may be found to burst transgressively through the older. In this way the eucrite and gabbro break through the peridotite group to the west of Trallval, and the acid rocks come to light in Fiadh-innis. The junctions between the several groups are in some places of a highly intricate nature, such as can be rendered only conventionally even on a large-scale map. The newer rock has sometimes penetrated the older in a network of ramifying veins; and has enclosed detached blocks of it, of all sizes, also intimately veined. The junction is thus not a line but a zone, which may have a width of a hundred yards or more. Such a zone of mechanical admixture may be termed for convenience an *intrusion-breccia.* It is found not only between the ultrabasic and the basic group, but also with remarkable development between different members of the former. In such cases there has been no noticeable chemical reaction between the twe rocks involved. Very different is the case where the invading magma was an acid one. In several parts of Rum mutual reactions between eucrite and granite have given rise to a remarkable set of mixed and hybrid rocks; and, in conjunction with contemporaneous crust-movements, have produced a group of gneisses.

In most of the foregoing particulars the plutonic rocks of Rum present a very close parallel to those of Skye. In the latter island we find also three groups, corresponding with those recognised above, though not petrographically identical; and they were intruded also in the same order, viz., the order of decreasing basicity. The same laccolitic habit characterises the larger intrusions, and the granite of the Red Hills passes under the gabbro of the Cuillins. A typical intrusion-breccia between peridotite and gabbro is seen in the neighbourhood of Loch Scavaig; and on Marsco and elsewhere the gabbro and granite have entered into remarkably intimate relations, giving rise to hybrid rocks, though not in this case to gneisses.

(ii.) GEOLOGICAL RELATIONS OF THE ULTRABASIC (PERIDOTITE-ALLIVALITE) GROUP.

The ultrabasic group builds most of the higher ground in the southern half of Rum. It makes Barkeval, Allival, Askival, and Trallval, and extends north-westward to near the head of Kilmory Glen, westward to the longitude of Harris, and south-westward to form the rugged ridge of Ruinseval and most of the precipitous coast between Harris and Papadil (fig. 20). This continuous area measures about 5¼ miles from north to south and 4¼ miles from east to west. In addition there are a number of small intrusions breaking through the Torridon sandstone of the northern part of the island, the most conspicuous being near Sgaorishal.

Since it is impossible to describe the relations of the rocks without distinguishing the *leading types* which occur, we shall anticipate to this extent the fuller petrographical description. Besides presenting by far the finest development of ultrabasic rocks in Britain, the group to be described exhibits some rather unusual petrographical characters. The rocks, like others of the same family, are poor in silica, very deficient in alkalies, and rich in magnesia; but they also contain in many of their varieties abundant lime and alumina. It follows that the principal minerals of the group, taken as a whole, are olivine and anorthite. Some pyroxene, monoclinic or rhombic, is generally present but the wide range of variety met with depends mainly on the different relative proportions of the two chief constituents named. We may regard as *true peridotites* those rocks in which olivine largely preponderates, the other elements being anorthite, pyroxenes, and chromite. These rocks are dark (often greenish) on a fractured face, and have a characteristic rusty weathering. The anorthite-olivine-rocks in which the two minerals are in approximately

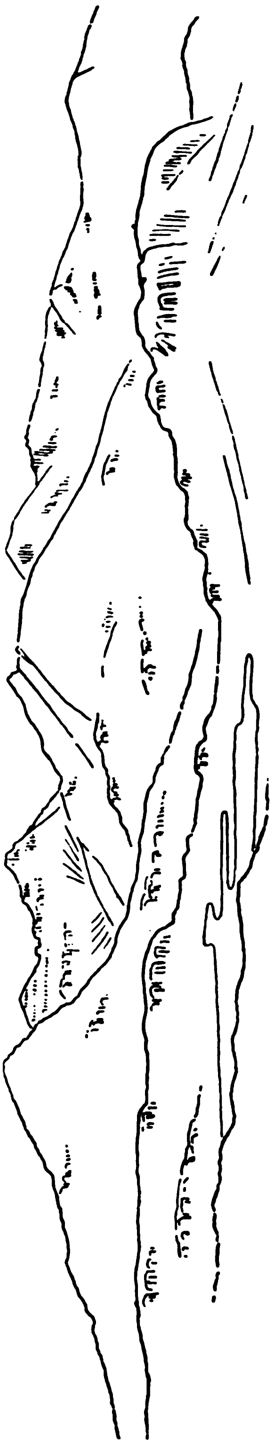

FIG. 20.—Outlines of the peridotite mountains of Rum, seen from above Loch an Dornabac, looking east and south. The summits, from left to right, are: Barkeval, Allival and Askival (closing in the head of Glen Harris), Trallval (in the centre), Ashval (behind) and Sgùrr nan Gillean, with the ridge of Ruinseval (these seen across Fiadh-innis). An Dornabac, the low hill in the foreground (right), is made by an intrusion of eucrite breaking through the peridotite group.

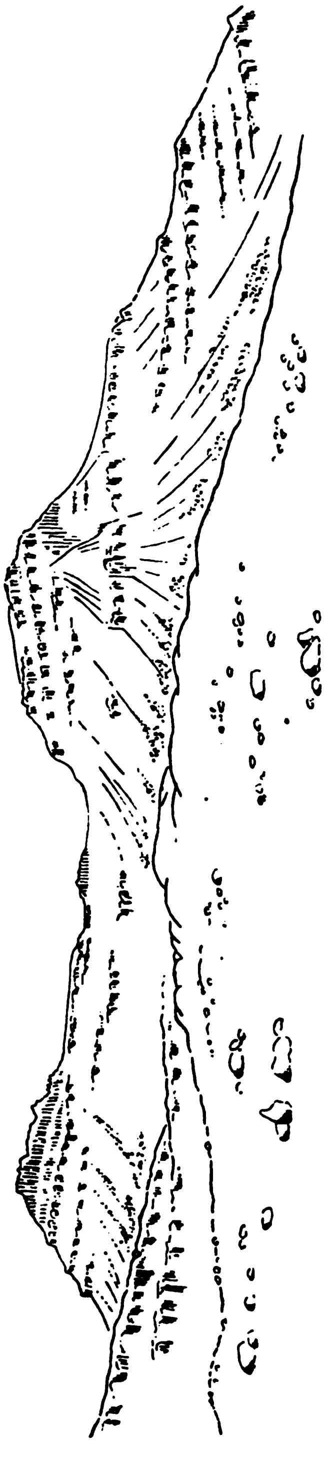

FIG. 21.—Outlines of Askival and Allival, seen from the east, from Coire nan Grunnd. The escarpments are made by sheets of allivalite, which alternate with peridotite. The platform on the left and the glaciated rocks in the foreground are of eucrite.

equal amount, or the felspar preponderates, will be styled *allivalites*. They are, in proportion to their more felspathic composition, pale rocks, and are very conspicuous in the field. Between the two types distinguished there are connecting links. We shall also find it convenient to denote by a special name another type which has both geological and petrographical individuality. This consists of largely preponderant olivine with anorthite and perhaps a little pyroxene, the olivine being of a peculiar black lustrous variety with good cleavage. This rock will be named *harrisite*.

Beginning in the east, a fine natural section of this part of the tract is presented in the steep slopes of *Allival* and *Askival*. The appearance of these mountains makes it difficult at first sight to believe that they are not carved out from a series of bedded sediments. Their flanks are terraced by strong escarpments, alternating with gentler slopes, the whole running with remarkable regularity round the mountains, with a general westerly dip. (See sketches, figs. 2 and 21.) This effect, already remarked by Sir Archibald Geikie,* is produced by sheets of allivalite and allied felspathic varieties alternating with types richer in olivine. The former make the salient features and the latter the retiring slopes (See section, fig. 22.) The allivalite sheets are usually from 50 to 100 feet thick, and the peridotite sheets from 100 to 150 feet. Closer examination shows that the individual sheets sometimes thin away and die out.

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* *Trans. Roy. Soc. Edin.*, vol. xxxv., pp. 132-136, and figs. 39, 40 (1888).

In addition to the general stratiform disposition, there is often, as Sir A. Geikie has also noticed, a strong *banding* within the several sheets themselves. This depends upon variations in the relative proportions of the component minerals, and especially of olivine and felspar. By differential weathering it often gives rise to a certain fluted appearance on a rock-face. The variation of composition in different bands of the same thick sheet is often not great; but sometimes thin bands depart widely in character from those with which they are associated. Thus the sheets of allivalite occasionally contain bands, a few inches thick, of pure anorthite-rock; while in the peridotites there are sometimes thin seams composed mainly of chromite or some other spinellid mineral, or again of augite. It is an invariable rule that the most extreme types occur only in narrow belts and seams.

Succession of ultrabasic group on Allival, as shown in fig. 22.

1. Peridotite, with felspar fairly abundant but very little augite.
2. Allivalite, with olivine and felspar in nearly equal proportions (Analysis III.).
3. Peridotite, with interstitial felspar.
4. Allivalite, typical.
5. Peridotite, with felspar.
6. Allivalite, rich in felspar.
7. Peridotite.
8. Allivalite, rich in felspar, with some augite.
9. Peridotite, approaching harrisite, but with plenty of felspar; nodular structure.
10. Allivalite, with ophitic augite.
11. Peridotite, with felspar; nodular structure.
12. Allivalite, felspathic, with bands of pure anorthite-rock.
13. Peridotite, with felspar; pitted surface from weathering of nodular patches free from felspar; some bands of olivine-rock.
14. Allivalite, with augite.
15. Peridotite, with pitted surface; felspar unevenly distributed and rock verges on allivalite.
16. Allivalite, very rich in felspar.
17. Peridotite, with pœcilitic felspar and augite.
18. Augite-Allivalite.
19. Anorthite-Peridotite.

Besides the general stratiform arrangement and the banding, there is a more or less marked tendency for the individual crystals to have a *parallel orientation*. This is not usually apparent in the true peridotites, for the olivine there does not form notably flat or elongated crystals; but the allivalites, and still more the nearly pure felspar-rocks, have a strongly fissile character, due to the parallel arrangement of the tabular crystals of felspar. It is to be remarked that in this part of the ultrabasic tract all parallel structures, whether on a large or on a small scale, have the same direction.

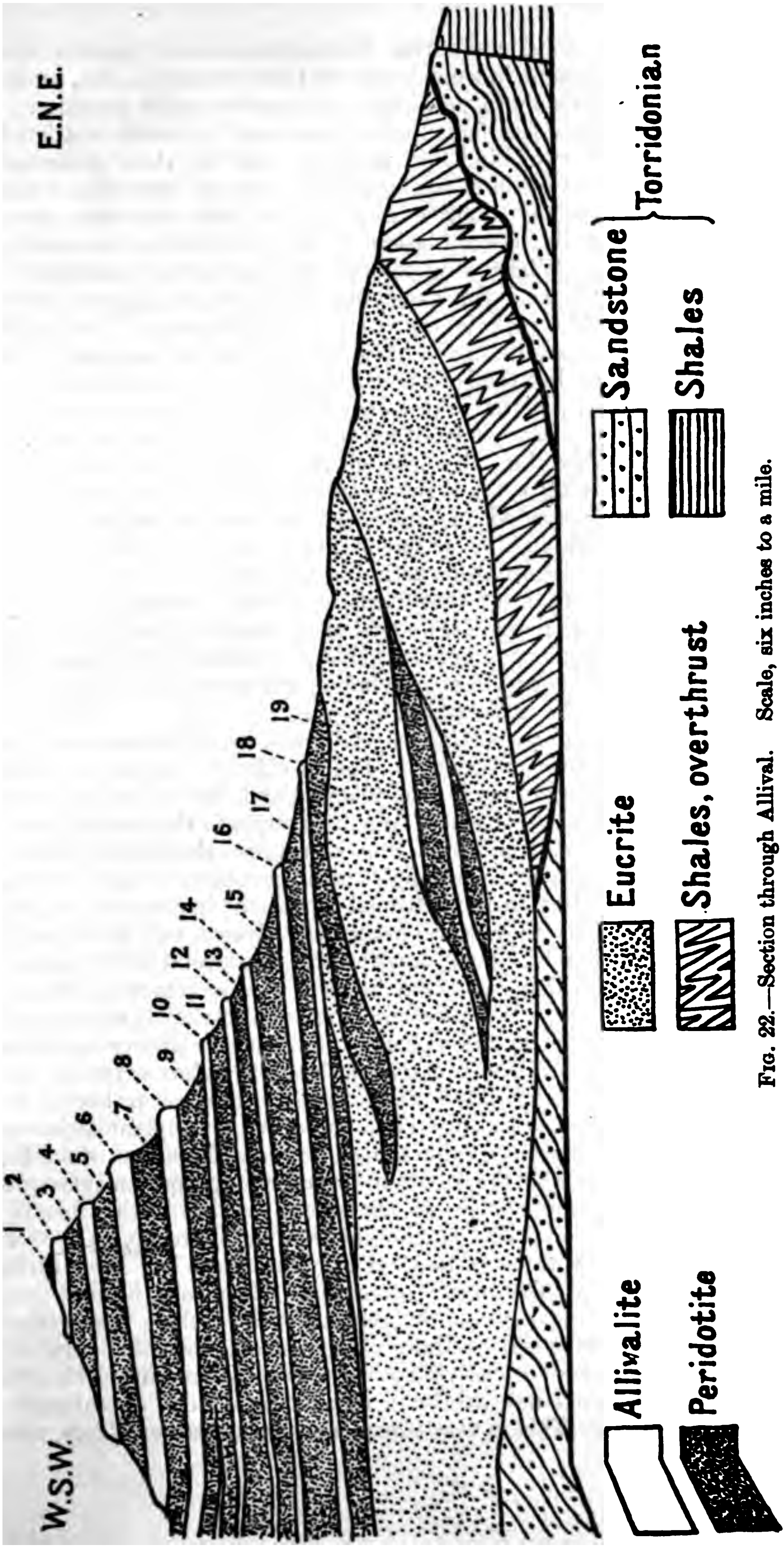

FIG. 22.—Section through Allival. Scale, six inches to a mile.

It cannot be doubted that the large sheets of peridotite and allivalite represent in some sense distinct intrusions, *i.e.*, separate inrushes of the more peridotic and more felspathic magmas. At the same time, the facts point to a very intimate relationship between the two kinds of magmas, and to their presumable derivation from a common source. The several intrusions seem to have followed one another very closely, with intervals scarcely sufficient for the consolidation of one sheet before the next one succeeded it. Where it is possible to examine the junction of an allivalite sheet with the overlying peridotite, it appears that the more felspathic rock is the younger of the two. The dividing surface, however, is not a clean-cut intrusive junction of the ordinary kind, but tends to be wavy, with irregularities on a small scale, suggesting that the newly-intruded magma was able in some degree to impress itself upon the still soft rock above it. It seems probable then that the allivalite sheets were not intruded into the peridotite after this was wholly solid; but that all the sheets were intruded in order as now seen, the uppermost first and the others in due succession, more peridotic and more felspathic magmas alternating with one another. The parallelism and regular disposition of the sheets of allivalite would be scarcely explicable on the supposition that they were intruded in the midst of a massive rock such as the peridotite; although the possibility of this as an incident is not excluded, and some local irregularities are perhaps to be explained in this way.

The magma of any single sheet-formed intrusion was not itself of quite uniform character. The peridotite magma contained portions somewhat richer in felspar, and the allivalite magma portions richer in olivine. We may suppose that at the time of the uprise of such a heterogeneous magma, the slightly different parts, which did not commingle, were associated irregularly with one another; but, in the fluxional movement incident to a stratiform intrusion, they were necessarily drawn out into parallel streaks and bands. Such must be the interpretation of much of the banding, which can often be seen to have something of a lenticular character. The parallel orientation of the crystals, more or less pronounced in different cases and most striking in certain highly felspathic bands in the allivalites, belongs to the same flowing movement. But while the magma of a given sheet is thus seen to have been partly differentiated, with incipient separation of the partial magmas, prior to its intrusion, there are often facts which point to a further differentiation and segregation subsequent to the intrusion of the sheet. It is possible that in thin bands of pure anorthite-rock and narrow seams of chromite or of pyroxene banding set up in the manner already indicated has been further accentuated by subsequent segregation. There are, however, more unequivocal indications of differentiation later than the cessation of flowing movement. Many of the thick sheets of peridotite, containing more or less felspar with the dominant olivine (and subsidiary pyroxene), exhibit a remarkably patchy appearance on a small scale. This is very conspicuous on a weathered face, where the more felspathic parts stand out in relief. Many of the rock-faces are pitted or even irregularly honeycombed, sometimes with cavities of rudely branching form. The salient parts often have forms resembling "concretionary" growths in impure calcareous or calcareo-argillaceous sediments, or, when more elaborately developed, recall the shapes of sponges and corals. More remarkable structures arise when effects of this kind have been superposed upon a well-marked fine banding. Here we find structures comparable with a certain type from the Magnesian Limestone of Durham, in which the concretionary growth has not obliterated the original lamination.

Summarily, then, we seem to have in this group of rocks an actual picture of differentiation, advanced in varying degree and arrested at various stages. Assuming the whole of the ultrabasic plutonic rocks of the Rum centre to come from a common parent-magma, this must have had a composition roughly equivalent to a mixture of olivine and anorthite (neglecting minor constituents), and there was a strong tendency for these two components to separate. In its deep-seated reservoir the magma was already partly differentiated at an early stage into a more peridotic and a more felspathic magma, and these two were so far separated that they were intruded in distinct sheets, apparently alternating with one another. A further differentiation on the same lines, but with only very imperfect separation, was already in progress in the partial magmas themselves as intruded. In so far as this had taken effect prior to the cessation of flowing movement, it gave rise to banded structures within the several sheets. The process of segregation was, however, continued somewhat farther, perhaps accentuating the banding in some measure, but certainly, in the peridotites especially, setting up a heterogeneity not related to the banding but superposed upon it.

The foregoing description of the ultrabasic rocks applies more particularly to Askival and Allival, where the stratiform arrangement of the group is most marked. The same sheets can be traced, for the most part, round the two mountains, though some of them thin away. The summit of Askival is made by a strong sheet of felspathic rock of unusual thickness, nearly 300 feet. Apparently the same sheet, with a thin cap of peridotite, forms the top of Allival, but it is here considerably reduced in thickness. It is noticeable that while on Allival this sheet is a typical allivalite, the thicker development on Askival is of a variety less well characterised, containing a noteworthy amount of pyroxene. Reckoning from the irregular upper surface of the eucrite below, the thickness of the series as seen on Allival is about 1500 feet. This is an under-estimate, for the summit is determined by erosion, and the base is not the original one, considerable lenticular masses of the ultrabasic rocks being enclosed in the eucrite east of Askival. Throughout this eastern area the inclination of the sheets, and of all the parallel structures associated with them, is inward, towards the centre of the ultrabasic tract. Thus on the mountains named the dip is W., to the north of Allival it is S.W., and to the south of Askival it is N.W. The same arrangement is discernible, though not always consistently, in the rest of the tract. Thus on Barkeval the dip is S.S.W., and farther west it is due S. This changes about Loch an Dornabac to S.E., then north of Harris to E., and near Harris itself to N.E. In the southern part of the tract, about Papadil, the general dip is about N. Local irregularities may be noted in some places. Thus, between Barkeval and An Dornabac, the general dip is west, instead of south. In such places the inclination is sometimes rather high, perhaps 40° or 50°, the usual angle being generally between 10° and 20°. Banding with a still steeper inclination, approaching the vertical, is found at some places on the northern edge of the tract; and it is parallel to the boundary of the mass, which here shows transgressive relations.

The alternating sheets can be followed from Allival west and north-west to Barkeval; but those composed of the more felspathic rocks (allivalite, &c.) become thinner and begin to die out. West of Barkeval they are always thin and inconstant, though one near Dornabac makes a considerable spread owing to its occupying a dip slope. This sheet encloses blocks and fragments of peridotite, and the same is true of the only conspicuously felspathic sheet seen in Glen Harris below the steep slopes at the head of the valley. It is probable that these particular sheets have been intruded in the midst of solid peridotite; but they still maintain a certain degree of regularity, and their inclination agrees with that of the general banding. On Trallval, 1¼ mile west of Askival, there are only two noticeable escarpments made by felspathic sheets, these being on the upper part of the hill; while in Fiadh-innis no distinct sheets very rich in felspar are found. Not only are sheets of felspathic rock rarer in the western part of the tract, but those which occur are not usually very typical allivalites, often containing a noteworthy amount of pyroxene, and approximating somewhat in character to olivine-eucrite. On Ruinseval, however, near the dip to the east of the summit, there are two sheets of allivalite of no great magnitude, one of them containing a band some inches thick of pure anorthite-rock.

It is difficult to judge whether the peridotites, which almost always contain more or less anorthite, become on the whole more felspathic westward; but, apart from this, the average composition of the whole group in the western part of the tract would seem to be richer in olivine and poorer in felspar than in the eastern part. Against this must be set the fact that in the west the peridotites are often traversed by a network of more felspathic veins, which in places make up a considerable part of the whole. These have often the character of typical allivalite, while in other places they are merely peridotites unusually rich in felspar. Although doubtless closely bound up with the rock in which they occur, they do not seem to be strictly contemporaneous or segregation-veins, but rather distinct later intrusions. They pass from one sheet to another of the peridotite, and enter the very distinct rock to be next mentioned. The felspathic veins are very abundant in an area extending along the eastern side of Abhuinn Sgathaig and across the floor of Glen Harris, and again to the west of Loch Fiadh-innis and Ruinseval. The boundaries of these areas do not correspond with the division of the peridotite into distinct sheets. The veins cannot be taken as proving that the allivalites are a distinct group of later intrusion; for in places, notably about Loch Sgathaig, lumps of allivalite a few inches in diameter occur abundantly in the peridotite. They are of more or less rounded form, not resembling broken pieces of a solid rock.

The most richly ferro-magnesian type, which may be described as a foliated olivine-rock, is found chiefly in the western part of the tract, and there in no great force. A sheet of it is seen at the north-westerly base of Ruinseval, and may be traced along the small burn south of Abhuinn Fiadh-innis and across this latter stream. The same or another sheet is seen again farther north, on the other side of the Glen Harris river, Abhuinn Rhangail. An occurrence of a somewhat different foliated olivine-rock may be noted on the road to the north-east of Harris.

There remains the remarkable rock which has been distinguished as *harrisite.* Several of the peridotite sheets in the eastern part of the tract have more or less of the characters of this type, notably on the ridge connecting Allival with Barkeval and at the head of Glen Harris; but the principal development of harrisite is in the extreme west, where it forms a distinct intrusion. It is manifestly later than the ordinary peridotites in the neighbourhood, and apparently later too than the felspathic veins in these rocks, for the veins are not found in the harrisite. It represents then a new invasion of ultrabasic magma, and is apparently the youngest member of this group. As seen to the north and N.N.E. of Harris, it forms the base of the ultrabasic succession, with a thickness of probably about 500 feet. (See section, fig. 23.) It extends along the road northward to beyond the Dornabac stables, while southward it can be followed to Abhuinn Rhangail, where it is cut off by the eucrite below. To the west of the road it rises on the hill Ard Mheall and occupies part of the opposite slope down into Glen Duibhal. The area exposed has a length of two miles and a maximum width of three-quarters of a mile. Most of the rock is well banded; and the banding follows the general shape of the sheet or flattened laccolite, which makes a shallow syncline on the top of the hill, and shows increasingly steep dips down into the Dornabac valley, until it disappears beneath the ordinary peridotites.

The junction of this harrisite intrusion with the overlying peridotite is a fine example of what we have styled an intrusion-breccia, the older rock being penetrated by innumerable veins of the younger, and the younger enclosing blocks and fragments of the older. The zone of mechanical intermingling attains in the neighbourhood of Loch an Dornabac a thickness of 200 or 250 feet, but there is no clear indication of fusion and incorporation.

We have mentioned that, in addition to the large continuous body of ultrabasic rocks, with the detached portions of it involved

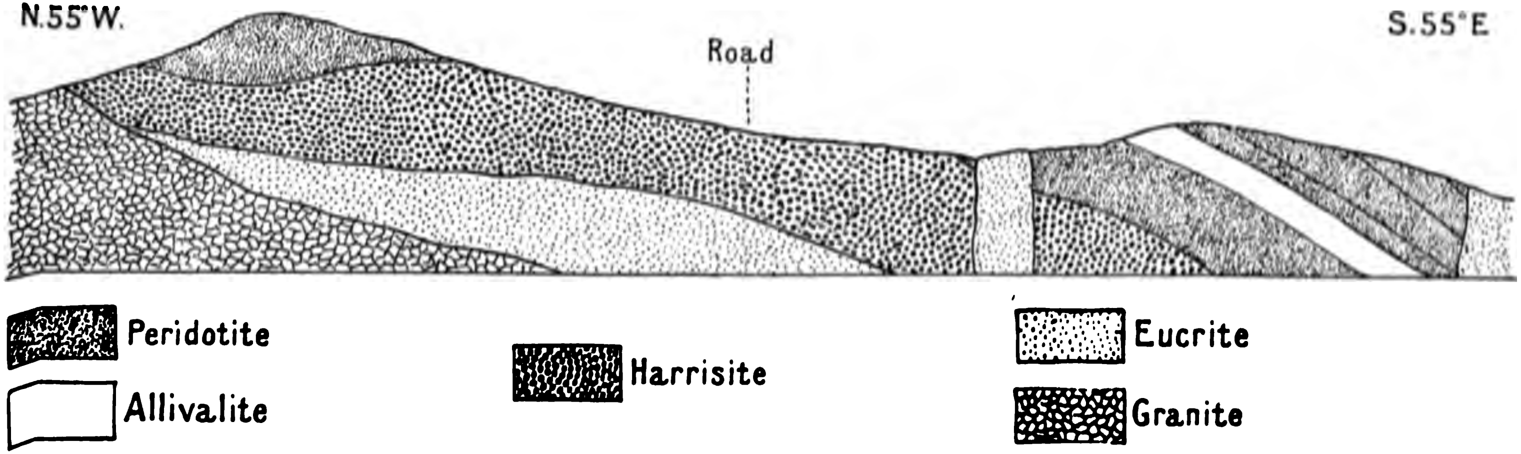

FIG. 23.—Section through Ard Mheall, north of Harris, Rum; to show the mutual relations of the various plutonic rocks. Scale, six inches to a mile.

in the eucrite, &c., there are *small independent intrusions* breaking through the Torridonian strata. About fifteen of these were mapped, ranging in dimensions up to about 700 yards. One, crossed by the road about 1½ mile west of Kinloch, is an irregular laccolite, but almost all the others break abruptly across the strata, with nearly vertical junctions, so far as can be ascertained. Petrographically, these small intrusions are all of peridotite, like the irregular northern fringe of the main body itself, the more felspathic types not being represented. As regards distribution, the small masses occur mostly to the north of the main body and towards Sgaorishal and the coast west of Kilmory. They are not found in the north-east, east, and west parts of the island. A line drawn to enclose all the occurrences gives a much-elongated oval, extending along a N.N.W.-S.S.E. axis, and the individual intrusions tend to have a similar extension (fig. 24). It agrees very nearly with the general (regional) direction of dykes in the Inner Hebrides, and is doubtless related to crustal strains of a regional order. Along the irregular northern border of the main body, however, the tendency is rather to a north–south extension. When the small intrusions show a banded structure, this is steeply inclined, and conforms with the boundary of the mass.

(iii.) PETROGRAPHY OF THE PERIDOTITE-ALLIVALITE GROUP.

To give a general idea of the *chemical composition* of the ultrabasic rocks of Rum, Dr. Pollard has made the four analyses here reproduced. The first is that of a peridotite with no very marked peculiarity, and the second compares somewhat closely with published analyses of dunites from New Zealand and America, though unusually rich in iron. Even in these two analyses, however, the noticeable amounts of alumina and lime are significant. The other two rocks are of more unusual composition, being rich in alumina and having magnesia partly replaced by lime. The series would be more complete if it included also one of the more felspathic allivalites, in which lime (with some soda) more completely takes the place of magnesia and iron-oxide, and the alumina rises still higher. The more felspathic rocks are also, of course, somewhat richer in silica. The low content of combined water in the four analyses shows that the rocks are in a much fresher condition than is usual among rocks rich in olivine. This constituent indeed never shows more than the early stages of serpentinisation, and the other minerals are quite fresh.

Some of the rock-types met with in the ultrabasic group of Rum have been described by Professor Judd,* who has also given a more particular account of the characters of the component minerals. The wide rage of variety among the rocks arises from the varying proportions of a small number of mineral elements. Of these, olivine and a felspar near anorthite occupy the first rank, while the others include rhombic and monoclinic pyroxenes and chromiferous members of the spinellid group.

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* "On the Tertiary and Older Peridotites of Scotland," *Quart. Journ. Geol. Soc.*, vol. xli., pp. 354–418, pls. x.-xiii. (1885). See also Teall, *Brit. Petrog.*, pl. v., fig. 1 (1888).

	I.	II.	III.	IV.
SiO_2 - -	39·04	39·16	42·20	40·82
TiO_2 - -	0·36	0·11	0·09	0·16
Al_2O_3 - -	2·89	1·11	17·56	10·66
Cr_2O_3 - -	0·45	0·61	0·06	0·25
Fe_2O_3 - -	2·80	2·47	1·20	1·80
FeO - -	7·78	11·44	6·33	8·92
MnO - -	0·24	0·15	0·18	0·19
(Co, Ni) O -	0·23	0·15	0·13	0·11
CuO - -	0·02	0·06	0·04	0·05
MgO - -	39·99	43·64	20·38	28·08
CaO - -	2·11	0·58	9·61	6·11
Na_2O - -	0·56	0·08	1·11	0·58
K_2O - -	0·09	0·16	0·11	0·21
H_2O above 105°	3·47	0·78	1·13	2·00
H_2O at 105° C.	0·15	0·02	0·06	0·16
S - -	0·06	0·04	0·02	0·02
CO_2 - -	tr.?	tr.	tr.	tr.
	100·24	100·56	100·21	100·12
S. calc. as FeS_2	0·11	0·08	0·04	0·04
Spec. grav. -	3·096	...	2·964	3·140

I. [10,448].—Peridotite, summit of Barkeval. Largely predominant olivine with anorthite, augite, enstatite, and chromite: anal. W. Pollard, *Summary of Progress of the Geological Survey* for 1903, p. 56.

II. [10,454].—Foliated olivine-rock, slope above Abhuinn Rhangail, 1400 yards east by north of Harris Lodge. Essentially of olivine, with a little anorthite and chromite: anal. W. Pollard, *ibid.*

III. [10,464].—Allivalite, 70 yards south of summit of Allival. Anorthite and olivine in nearly equal proportions, with a very little augite and magnetite: anal. W. Pollard, *ibid.*

IV. [10,461].—Harrisite, roadside near Dornabac Bridge, north of Harris. About three times as much olivine as anorthite, with augite in very subordinate quantity: anal. W. Pollard, *ibid.*

The *olivine*, when idiomorphic, has more or less of a tabular habit, the broad faces being parallel to (010), while the other prominent faces in the prism-zone are those of the form (110) or sometimes (100).* Inclusions of magnetite are very general, and are usually dendritic growths enclosed in flat rectangular cavities, as described by Professor Judd. Of these there may be two sets, parallel to the two pinacoidal directions: where only one set is developed, it is usually, but not always, that parallel to (100). Occasionally the inclusions attain relatively large dimensions. The pinacoidal cleavages are often noticeable, especially that parallel to the broad faces (010).

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* We follow the general practice of orienting the crystal in the manner of Dana, not of Miller.

It is a remarkable fact that the olivine in these rocks is of two quite distinct varieties, which occur either separately or not infrequently associated in the same rock. We may distinguish them as the green and the black. The former, which is the more common, has the deep olive-green colour usual in fresh peridotites or the yellower tint met with in many basalts. The tabular habit is not very pronounced, and the angles are commonly rounded. The cleavage is scarcely noticeable on a hand-specimen, though in a thin slice the cracks parallel to (010) are often fairly regular.

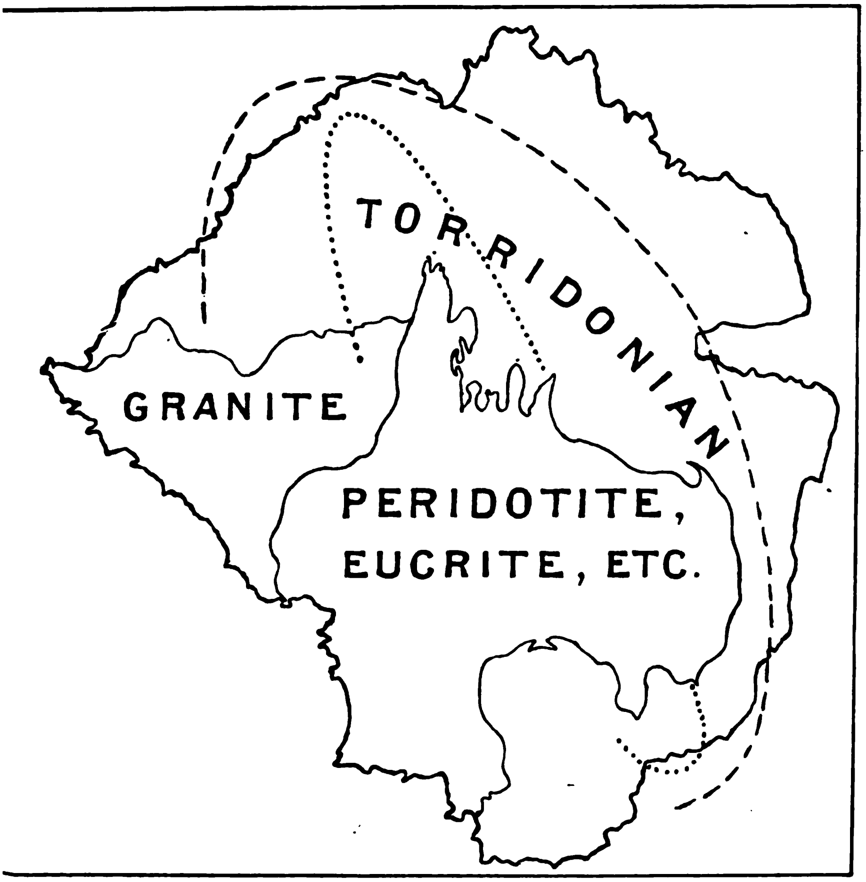

FIG. 24.—Sketch-map to show the distribution of the smaller plutonic intrusions in Rum Scale, half an inch to a mile.

The outlines of the larger masses are indicated in a generalised fashion, and the areas affected by the smaller masses are enclosed by oval curves, the dotted line belonging to the ultrabasic rocks (peridotites) and the broken line to the basic (eucrite and gabbro).

The second variety often builds rather large crystals, sometimes an inch in length, excluding pegmatoid rocks, in which the crystals may reach the size of six inches. The habit is rectangular and flattened, the prominent planes being the two pinacoid forms and the basal, and the crystals are usually more perfect than those of the green variety. Twin-lamellation is not uncommon [10,454, &c.], though it is rarely very noticeable in thin slices. The twin-plane is probably the dome (011). The colour is a lustrous black, with none of the translucency of the green mineral; and this, with the fact that the cleavages are much more pronounced than is usual in olivine, gives this black variety an extraordinary resemblance to a pyroxene. It is the characteristic mineral of the harrisites and of some foliated olivine-rocks; but it is also found in some of the other peridotites, and is there associated with the commoner green variety. The difference in appearance between the two kinds of olivine is not easily explained. Both become colourless in thin slices, and they are equally affected by inclusions of the "schiller" type. Nor is there any great difference in chemical composition. Professor Heddle made an analysis (V.) of the common olivine from Allival, which shows it to be rather highly ferriferous. Of 33 analyses of olivine (excluding forsterite on the one hand and hyalosiderite and fayalite on the other) given in Hintze's *Handbuch der Mineralogie*, only three are richer in iron. One of these, from a Norwegian rock comparable with the Rum allivalites, is quoted in Column A. Dr. Pollard's analysis (III.)

	V.	VI.	A.
SiO_2 - -	38·006	39·35	38·30
TiO_2 - -	...	0·11	...
Al_2O_3 - -	0·286	...	...
Fe_2O_3 - -	2·933	2·58	...
FeO - -	18·703	11·09	24·02
MnO - -	0·100	0·16	...
$(Co, Ni)O$ - -	...	0·16	...
CuO - -	...	0·06	...
MgO - -	38·000	45·27	38·29
CaO - -	0·336	0·39	...
H_2O above 100°	1·587	0·81	...
H_2O at 100°C.		0·02	...
	99·945	100·00	100·61
Spec. grav. - -	3·327	...	...

V.—Green olivine, from peridotite (anorthite-peridotite) near summit of Allival: anal. M. F. Heddle, *Min. Mag.*, vol. v., p. 16 (1882).

VI.—Black olivine, from foliated olivine-rock of Analysis II. above, calculated to 100 *per cent.* after rejecting the chromite, pyrites, and felspar.

A.—Olivine, from anorthite-olivine-rock, Skurruvuselv, Norway: anal. Th. Hjortdahl, *Nyt. Mag. Naturv.*, vol. xxiii.

shows that in the allivalites, as well as in the peridotites, the olivine is decidedly rich in iron. The black olivine, of which the calculated composition is given under VI., has less iron and more magnesia. The ferric oxide in both cases is doubtless contained largely in the minute inclusions of magnetite.

While the olivine in all the rocks is usually quite fresh, the beginning of serpentinous change may sometimes be seen along the cracks. Veinlets of yellow serpentine have been formed, which are double, with more or less finely granular magnetite along the median line. A certain expansion accompanying this change has sometimes produced radiating fissures traversing the contiguous felspar.

The *felspar* is always ot a very basic kind, rich in lime. This is indicated by the analyses of the rocks, and is confirmed by measurements of extinction-angles, both in thin slices and in cleavage-flakes, pointing to varieties of anorthite and sometimes of bytownite. The specific gravity of a pure felspar-rock from the banded allivalites at the head of Glen Harris was found to be 2·740, and the felspar of the typical harrisite of Dornabac bridge gave 2·714. In the ordinary peridotites the felspar invariably shows albite and pericline lamellæ, sometimes rather closely set, but carlsbad twins are rare: in the allivalites the albite-lamellation is almost always combined with twinning on the carlsbad law, while pericline twinning is often less developed. The crystals are perfectly limpid in thin slices, and rarely contain inclusions of any kind. Heddle remarks that the felspar of Allival (which he speaks of as labradorite) is "the most pellucid in Scotland."

The *augite*, like the olivine, appears, as Heddle has remarked, in two distinct varieties, a black and a green. The common kind is black on hand-specimens, with the usual perfect prismatic cleavage. In thin slices it shows a pale yellow or brownish tint. In a few of the peridotites it has a diallagic structure, while the augite which occurs as an accessory in some allivalites has not infrequently a fine lamellation and "schiller" structure parallel to the basal plane. The second variety of augite, of less common occurrence, is bright green and translucent on hand-specimens, and has a much less distinct cleavage; insomuch that it was mistaken by Jameson for pitchstone. Macculloch* likened it to coccolite. In thin slices it has a very pale-green tint, and it is not affected by "schiller" structures. As Professor Judd has remarked, the characters are very like those of the chrome-diopside in the Pyrenæan lherzolites. Unfortunately in an analysis of the green augite by Professor Heddle, reproduced in Column VII., chromium was not estimated. It is noteworthy that the content of iron is not high. The molecular ratios are

$$\begin{array}{ccccc} FeO & : & MgO & : & CaO \\ 0{\cdot}02 & : & 1{\cdot}11 & : & 1{\cdot}00 \end{array}$$

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* *Description of the Western Islands of Scotland*, vol. i., p. 503 (1819). Macculloch describes the green augite as occurring with the black and enclosed or intergrown in it; but it is probable that he mistook black cleaved olivine for augite. He certainly mistook common green olivine also for augite, his "augit-rock" being the peridotite.

In the augites of the Skye gabbros the corresponding ratios
range from 0·55 : 1·05 : 1·00
to 0·34 : 1·11 : 1·00

A remarkable feature of the green augite of Rum is its high density. Of 158 specific gravities of augites given by Hintze only four are higher, the average being 3·283.

Of the *rhombic pyroxenes* of the Rum peridotites we possess no analyses; but the fact that the mineral is always sensibly colourless in thin slices shows that it is not of a ferriferous variety, and we may safely term it enstatite.* The prismatic cleavage is well developed. There are occasionally a few inclusions of magnetite, resembling some found in the olivine, but no distinct "schiller" structure is found. Both augite and enstatite sometimes occur as narrow borders interposed between olivine and felspar; but there is nothing to suggest a secondary origin.

		VII.	B.
SiO_2	-	50·537	53·63
Al_2O_3	-	3·348	4·07
Cr_2O_3	-	not det.	1·30
Fe_2O_3	-	1·338	...
FeO	-	4·423	8·52
MnO	-	0·23	...
MgO	-	17·05	12·48
CaO	-	21·419	20·37
Na_2O	-	0·53	...
K_2O	-	0·252	...
H_2O	-	0·706	...
		99·833	100·37
Spec. grav.		3·481	...

VII.—Green augite from peridotite near the summit of Allival: anal. M. F. Heddle, *Trans. Roy. Soc. Edin.*, vol. xxviii., p. 478 (1878).

B.—Green augite (chrome-diopside), from peridotite (lherzolite), L. Lherz, Ariège: anal. A. Damour, *Bull. Soc. Géol. Fra.*, vol. xix., p. 413 (1862).

All the rocks contain in small quantity an opaque octahedral mineral of the *spinel group*. It is very sparingly present in the felspathic allivalites, and especially in the pure anorthite-rocks; but in the peridotites it is a more noticeable constituent, and occasionally forms distinct narrow seams of almost pure material. The crystals are commonly about $\frac{1}{100}$ inch in diameter, smaller in the felspathic rocks, but $\frac{1}{50}$ inch or more in the seams. Here the mineral appears black with a lustre approaching the metallic; while in thin slices it is almost constantly opaque. The rock-analyses indicate a chromiferous mineral, and it is possible that both true chromite and chrome-magnetite occur. The distinct seams, which are non-magnetic, are chromite, as proved by Professor Heddle. His analysis was made on somewhat impure material, containing a little felspar and olivine, and was moreover confessedly imperfect, as appears from the abnormally high total. The considerable amounts of alumina and magnesia (allowing for the impurities) point to a variety intermediate between chromite proper and picotite, and the content of chromium is decidedly low. The translucent brown picotite found in some of the Skye peridotites (see Analysis D) has been noticed only once or twice in our slices of Rum rocks, and the transparent green pleonaste has not been observed.

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* The "hypersthene" which Macculloch recorded in the neighbourhood of Harris is probably the black cleavable olivine of the coarse pegmatoid harrisite.

	VIII.		C.	D.
SiO_2	6·543	6·236	7·30	1·19
TiO_2	...	...	...	0·34
Al_2O_3	17·957	18·279	16·77	46·54
Cr_2O_3	26·304	26·343	31·48	17·55
Fe_2O_3	not det.	not det.	...	6·01
FeO	34·239	34·112	29·60	10·10
NiO, CoO	...	...	...	0·24
MnO	0·869	0·752	...	trace.
MgO	13·913	14·086	14·85	18·35
CaO	6·573	6·382	...	0·43
	106·398	106·191	100·00	100·75
Spec. grav.	4·163		...	(3·78)

VIII.—Chromite (impure), seam quarter of an inch thick in belt of olivine-rock in banded peridotite, near summit on north-west front of Askival: anal. M. F. Heddle, *Trans. Roy. Soc. Edin.*, vol. xxx., p. 461 (1882).

C.—Chromite (impure), Hungary: anal. J. Clouet, *Ann. Chim. Phys.* (4), vol. xvi., p. 90 (1869).

D.—Picotite, seam in banded dunite, glen south of Allt a' Chaoich, Loch Scavaig, Skye: anal. W. Pollard, *Mem. Geol. Sur.*, *Tertiary Igneous Rocks of Skye*, p. 70 (1904).

The minerals enumerated almost exhaust the list of constituents. Many of the slices show small scraps of brown hornblende and biotite, closely associated with pyroxene and olivine; but they occur only in negligeable quantity. Pyrites may be present up to 0·1 *per cent.*, as shown by the analyses of the rocks. Perofskite and apatite have not been detected.

An examination of the *order of crystallisation* of the several constituents in our ultrabasic rocks leads to some observations of interest. Selecting varieties free, or practically free, from pyroxene, and disregarding the very small amount of chromite present, we can study a series of rocks composed merely of olivine and felspar, and, in different examples, containing these two constituents in all relative proportions. We find that three cases are illustrated. (See fig. 25.) (*a*) When the rock is rich in olivine, that mineral has crystallised first. (*b*) When the rock is very rich in felspar, the felspar has crystallised first. (*c*) When there is richness in felspar, but not so great a preponderance as in the last case, the two minerals have crystallised together, so that in different parts of a thin slice one or other presents crystal-faces. This is entirely in accordance with the solution-hypothesis as applied to rock-magmas by Vogt.* In the third case olivine and felspar are present practically in the eutectic proportions. In the first case olivine and in the second case felspar is in excess as compared with eutectic proportions, and that constituent accordingly began to crystallise when the temperature had fallen sufficiently.

Turning to rocks in which a pyroxene is present in notable amount, in addition to olivine and felspar, we see a different rule. Here the olivine has invariably crystallised before either felspar or augite, even when it is not present in very large amount. The influence of the pyroxene, in causing the olivine to crystallise earlier than it would otherwise do, seems to fall under Nernst's law of the reduction of solubility between substances having a common ion.† Olivine and pyroxene have the ion (Mg, Fe) in common, and the former mineral (the less soluble) has its solubility in consequence considerably reduced. The same law applies with greater

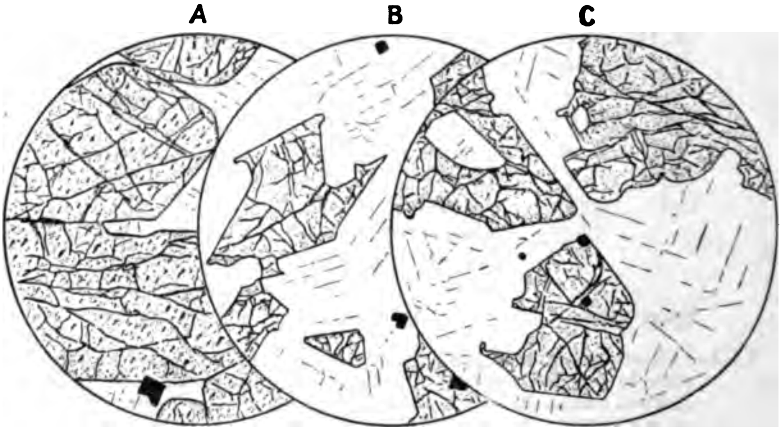

FIG. 25.—Olivine-Anorthite-rocks ; × 20.

A. [10,457].—170 yards south by west of summit of Allival. Olivine in excess, and idiomorphic towards felspar.
B. [10,467].—Near Barkeval Pass. Felspar in excess, and idiomorphic towards olivine.
C. [10,465].—East face of Askival, at 2150 feet. Eutectic proportions, the two minerals crystallised simultaneously. The small opaque crystals are chromite.

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* Die Silikatschmelzlösungen, *Vidensk.—Selsk. Skr., Math.—Naturv. Klasse,* 1903, No. 8, and 1904, No. 1.

† W. Nernst, *Theoretische Chemie,* 3rd ed. (1900), p. 492.

force to the chromite, which also has (Mg, Fe) as cation, and this mineral is almost invariably found to have crystallised first of all. Only in one slice has the chromite been observed sometimes to mould itself upon the olivine crystals.

We proceed to notice some of the principal characters of the rocks themselves. Among the peridotites there are some composed practically of olivine alone, the only other mineral being a little chromite. There is usually a more or less pronounced fissility due to a parallel disposition of the tabular crystals. There are two varieties of *olivine-rock*, the one composed of green and the other of black olivine. The former may be termed a foliated dunite. A good example is found where the road crosses a burn about three-quarters of a mile north-east by north of Harris Lodge. It is a moderately coarse-grained olive-green rock composed of olivine and rather abundant chromite [10,966]. Its specific gravity is 3·280.* Rocks composed of the black cleavable olivine form a sheet crossing Abhuinn Fiadh-innis and the lower part of Glen Harris, as already noticed, and are found also in one or two other places. A specimen from the first-named place gave the specific gravity 3·307. An example from Glen Harris has been analysed, and the result is given in Column II., above. In the escarpment at the head of Glen Harris and at one or two other places occur olivine-rocks, in which the black and the green varieties are associated together. One specimen [11,676] shows lustrous black crystals up to nearly an inch in length, set in an aggregate of smaller crystals of greenish-yellow colour. In this rock there is a little anorthite, besides the usual chromite. There are varieties also of the black olivine-rock which contain very small amounts of anorthite and augite; and one, from Abhuinn Fiadh-innis, has instead a small proportion of enstatite. All these olivine-rocks have a fissile structure in some measure, and they tend to break up rather easily under the hammer.

The *peridotites of less extreme type* present a great range of variety. They have a rusty weathered surface, and a dark-green colour when broken; but both on an exposed face and on a fresh fracture some white felspar is usually visible, and sometimes a little black pyroxene also. These minerals are always interstitial to the olivine crystals, and sometimes it can be seen that adjacent portions of felspar (or pyroxene) are parts of one large crystal enwrapping and enclosing numerous olivines in "pœcilitic" fashion, a peculiarity remarked by Macculloch. Of minerals other than olivine (and the ubiquitous chromite) felspar is the most constant, and is only exceptionally exceeded in quantity by pyroxene.† Of the two pyroxenes, it is found in thin slices that augite is the commoner, though there are examples in which enstatite preponderates [10,451, &c.]. In most of the rocks there is a tendency, as already remarked, to variation in the relative amounts of the constituents, often assuming some nodular form, and giving rise to peculiar appearances on a weathered face. A tendency to banding is often apparent. Occasionally there are bands of almost pure olivine-rock, as at the head of Glen Harris; or again seams of chromite, which are usually not more than an inch thick, and may pass rather irregularly into the containing rock. A parallel arrangement of crystals is not often noticeable. The appearance of the peridotites in the field is sometimes further diversified, especially in the western part of the tract, by a network of veins of allivalite or allied felspathic rocks; or, less commonly there are numerous irregularly rounded lumps of allivalite enclosed in the peridotite, as about the valley of Loch Sgathaig.

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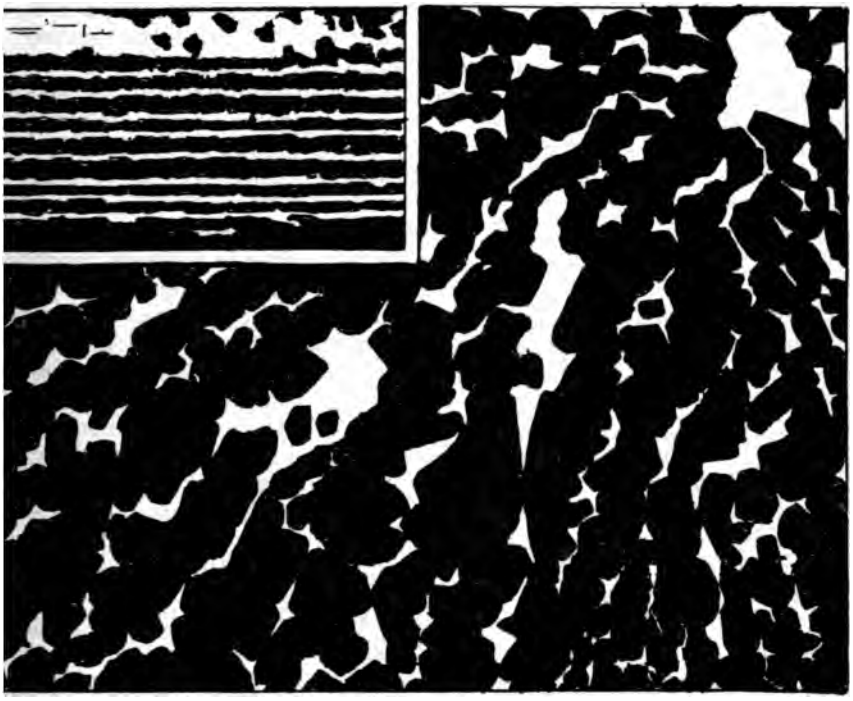
* Throughout this memoir specific gravities given to three places of decimals have been determined by the hydrostatic balance and corrected for temperature (to water at 4° C.) Results given to two places of decimals have been obtained with Walker's balance.

† A peridotite (picrite) from Allival is figured in Teall's *British Petrography*, pl. v., fig. 1 (1886).

A highly characteristic rock is the special type of peridotite which we have designated *harrisite*, since its peculiar nature seems to render a distinctive name desirable. It consists typically of black cleavable olivine and a felspar near anorthite in composition, the former mineral being usually greatly preponderant, while the accessory constituents are chromite and sometimes a little pyroxene. In the example analysed (see Column IV., above) the olivine is about three times as abundant as the felspar. Another specimen from the same neighbourhood gave the specific gravity 3·168, indicating about four times as much olivine as felspar. Where subordinate pyroxene enters, it is often enstatite. The harrisite is often of coarsely crystalline texture, and the contrast of lustrous black olivine with pure white felspar renders it a remarkably handsome rock. Indeed much of the rock exposed along the roadside near Dornabac bridge is of *pegmatoid* character. Sometimes the white interstitial patches of felspar between the black crystals of olivine tend to run into irregular strings, which look like veins of calcite. There may be a common crystallographic orientation along a considerable part of such a string, clearly shown by the twin-lamellæ visible on the bright surface. The irregular vein-like strings of felspar do not tend to parallelism, as if part of a banded structure, but in places have a well-marked radiate arrangement about certain centres, the complex growths thus outlined having a diameter of from two to four feet. (See fig. 26.) Again we find graphic pegmatite of the lamellar kind, the alternating plates of black olivine and white felspar usually numbering about twenty in an inch of width. A few grains of green olivine are sometimes associated with the black, but the green variety does not enter into intergrowths with the felspar. Scattered flakes of golden-brown mica are not uncommon. The individual crystals of olivine in these pegmatoid varieties of harrisite attain dimensions of from four to six inches.

The typical harrisite graduates, in the Harris district itself, into varieties containing a somewhat larger proportion of felspar. Rocks resembling these latter occur also in the eastern part of the tract, as at some places on the lower slopes of Allival and again in some force about the Barkeval pass. Here the black olivine is generally associated with the green, and the rocks pass into others of more ordinary type, in which the olivine is all of the common variety. Rocks of the latter type, consisting essentially of dominant olivine and a fair amount of felspar, with little pyroxene, are perhaps the most widespread of all. They may be conveniently distinguished as *anorthite-peridotites.* With increasing quantity of felspar they afford connecting links with the allivalite type. The average anorthite-peridotite has a specific gravity about 3·0 to 3·1, the peridotites with less felspar ranging from 3·1 to 3·3.

The simple *allivalite* consists of anorthite and olivine, with only trifling proportions of any other element, the felspar equalling or exceeding the olivine. The existence of such rocks in Rum has been recognised by Professor Judd* and by Sir Archibald Geikie,† the former giving some petrographical description and the latter remarking the bedded appearance of the rock and the fluxional arrangement of the felspar crystals. These geologists term the rock troctolite, and the same name was used, under protest, by the



IG. 26.—Structures in harrisite, between Dornabac and Harris, Rum; natural size. Showing the vein-like occurrence of felspar, with a rough radiate arrangement; also (in the smaller figure) a lamellar intergrowth of the two minerals.

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* *Quart. Journ. Geol. Soc.*, vol. xli., p. 395, and pl. xiii., fig. 5 (1885).

† *Trans. Roy. Soc. Edin.*, vol. xxxv., pp. 135, 136 (1888).

present writer in describing a similar rock associated with the peridotites of Skye.* The use of this term is, however, misleading, for the true troctolite is a varietal form of gabbro and is typically a labradorite-bearing rock. The troctolite of Coverack in Cornwall contains labradorite of medium composition, and the same is true of the Beihelvie rock in Aberdeenshire, though the troctolite of Volpersdorf in Silesia has apparently a bytownite. The rocks of Rum and Skye clearly belong to the ultrabasic family, and their mineralogical nature no less than their affinities must lead to their being separated from the troctolites under a distinctive name.

In the field the allivalites are conspicuous by their pale colour, showing a white surface dotted with dark or rusty orange spots which represent the olivine-grains. The olivine here is of the common green kind. Its abundance relatively to the felspar varies in different examples, so that the allivalites graduate on the one hand into what we have called anorthite-peridotites and on the other hand into pure anorthite-rock. In the specimen analysed (see Column III., above) the felspar is not greatly in excess of the olivine. A specimen from the east slope of Allival gave the specific gravity 2·877, and another from the Barkeval pass 2·883. These are more felspathic varieties, with about 70 *per cent.* of anorthite. The composition sometimes varies considerably in different bands of a single sheet, some being richer and others poorer in olivine, and such variation may occur in quite thin alternations. Where augite enters in notable quantity in addition to the dominant anorthite and olivine, the rock may be distinguised as *augite-allivalite*, and this variety is met with in some of the sheets on Allival, Askival, Trallval, and elsewhere. Here there are sometimes alternating bands less than half an inch thick marked by relative richness in olivine and augite respectively. In a typical allivalite in the upper part of Askival, besides thin seams of augite-allivalite, there are others almost wholly of augite in irregularly interlocking crystals half an inch to one inch long [10,469]. Almost all the allivalites have a very decided tendency to parallel allignment of the crystals of felspar, and to some extent of olivine, which imparts a fissile character to the rock.

This fissile character is especially pronounced in the pure *anorthite-rock*, which is the extreme felspathic member of the group. This rock does not occur in any force, but merely constitutes bands in some of the allivalite sheets, some bands being only a few inches thick. A specimen from the head of Glen Harris was found to have the specific gravity 2·740, which may be taken as indicating a nearly pure lime-felspar.

The whole assemblage of ultrabasic rocks, ranging from a purely peridotic to a purely felspathic type, with the closest association between them, seems to afford a striking illustration of *magmatic differentiation*. It is scarcely possible to avoid the inference that these very different rocks have been derived from one ultimate source: that the olivine and anorthite molecules existed as such in the fluid magma, at least at that stage when crystallisation became imminent; and that between these two there was in effect—from whatever physical cause—a decided mutual repulsion. The tendency to separation is evinced at every stage from the presumed general parent magma to the rocks as finally consolidated. The chromite went with the olivine. The same is true of the accessory biotite; though this mineral, with its complex molecule containing some isomer of olivine as part of its constitution, probably did not exist as such in the magma until the point of crystallisation was approached. The behaviour of the pyroxenes was more indifferent, but these also have shared in differentiation of a further order.

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* *Tertiary Igneous Rocks of Skye*, p. 73 (1904).

The progressive separation between olivine and anorthite is perhaps capable of explanation on physico-chemical principles. Experiment shows* that augite on the one hand and olivine and anorthite on the other are connected by a reversible relation expressed in the equation—

$$\begin{array}{lcl} CaMgSi_2O_6 + MgAl_2SiO_6 & = & Mg_2SiO_4 + CaAl_2Si_2O_8 \\ \underbrace{\text{Diopside} + \text{Tschermak's silicate}}_{\text{Augite.}} & = & \text{Olivine} + \text{Anorthite} \end{array}$$

Under different conditions the reaction proceeds in one or the other direction. Since the augite molecule is known to be one which is stable at high temperatures, it may be suggested that the original magma was an augitic one, and that, with falling temperature, there was a splitting up of the augite molecule into olivine and anorthite.

These rocks serve also, as has been shown, to illustrate the conditions of crystallisation and the circumstances which determine the order of consolidation of the several constituents. In this connection the simultaneous crystallisation of olivine and felspar in the pegmatoid harrisite, with graphic structure, is of special interest.

Finally, the petrographical characters and mutual relationship of the various types included in this natural group of rocks give rise to certain reflections (which will be only briefly suggested here) concerning the classification of the ultrabasic plutonic rocks in general. Petrographers have usually considered the absence of felspar as a prime characteristic of the ultrabasic family, and to group together the peridotites and pyroxenites, as Rosenbusch and others have done, can only be justified by laying stress on this negative character. Setting aside rocks extremely rich in iron-ore minerals, which occur as special facies rather than as individual rock-bodies, the ideal ultrabasic rock is one consisting essentially of olivine, with some proportion of a spinellid mineral. This may be regarded as the extreme type, which may be reached along one or other of different converging lines. The pyroxene-olivine-rocks and the anorthite-olivine-rocks are two such lines, and the latter seems to be as much entitled to recognition as the former.

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* See Doelter, *Physikalisch-chemische Mineralogie* (1905), p. 121.

Anorthite of ideal composition (which, however, is not always the case in these Rum rocks) is poorer in silica than the ordinary pyroxenes, and is equally devoid of alkalies. Considered with reference to their several associations, as indicative of their true affinities, a pure lime-felspar-rock would seem to have more claim to rank as an ultrabasic type than a pure pyroxene-rock, for the latter is in most known occurrences a varietal form, not of peridotite, but of gabbro or norite. The ultrabasic rocks rich in felspar have, on the other hand, in Rum at least, been derived by differentiation from a felspar-olivine-magma, the complementary products of the differentiation being true peridotites. The rocks holding a corresponding position in the gabbro family, viz., the troctolites, have as their dominant constituent labradorite or labradorite-bytownite, instead of anorthite or bytownite-anorthite. The term "anorthosite" has been expressly avoided in the foregoing remarks, since there can be no place in rational petrology for a name covering rock-types which have such very diverse affinities and range in composition from albite-rock to anorthite-rock.

CHAPTER VIII.

PLUTONIC ROCKS: BASIC (RUM AND MUCK).

(i.) GEOLOGICAL RELATIONS OF THE BASIC (EUCRITE AND GABBRO) GROUP.

In Rum, as in Skye, the ultrabasic plutonic intrusions were succeeded by others of basic rocks. The relative importance of the two groups is not the same in the two islands. In Skye the peridotites were not developed on a very large scale, and they became completely enveloped by the much more voluminous intrusions of gabbro which followed. In Rum there was a more extensive, as well as a more varied, development of the ultrabasic group, and the basic rocks are probably somewhat inferior in total bulk. The fact that the latter rocks are less in evidence on the ground than the former is, however, partly a consequence of their infraposition, for they doubtless underlie the peridotites, allivalites, and harrisites in the interior of the mountain tract.

The basic plutonic rocks of Skye are gabbros, having as their felspathic constituent labradorite, or only exceptionally bytownite. The corresponding rocks of Rum belong for the most part to somewhat different types, with bytownite or anorthite. With this difference in the felspars go other points of distinction, such as a greater richness in olivine and a very general association of rhombic pyroxene with the monoclinic; and we shall mark the distinction by naming rocks of this kind *eucrites*. With them are found also types which fall under the head of *gabbro*, but these are certainly in much less force. In so far as the relations of the complex have been deciphered, it appears that the gabbros are in general of later intrusion than the eucrites; but our observations do not enable us to lay this down as a general rule, and it has not been found practicable to separate the two on the map. In referring to the basic plutonic rocks of Rum collectively, we shall, with this understanding, use the name eucrite, which is appropriate to the major part of the assemblage.

The main outcrop of the group makes an irregular and discontinuous belt round the mountain tract of the southern half of Rum. The arrangement is most evident on the east side, where the eucrite, with distinct stratiform disposition, rests on the Torridonian rocks nearly at the horizon of the overthrust (figs. 4, 5, and 22). Even here sheets and tongues interlace on the slopes of Askival with the sheets of peridotite and allivalite; and lower down lenticles of these ultrabasic rocks occur within the eucrite-gabbro complex, being intercepted between the component sheets of the latter. In this way, as well as by differences of texture and composition in different sheets, it is made manifest that the laccolitic mass of basic rocks has been built up by numerous distinct intrusions. Banded structures are very prevalent, though usually of a less pronounced kind than those in the ultrabasic group. They have the same general inclination towards the centre of the tract, the angle of dip in this part of the belt varying between 15° and 20°. Followed northward, the eucrite becomes diminished in thickness, and after crossing Coire Dubh it is reduced to less than 500 feet, as compared with nearly 2000 feet on the slopes of Askival. Near Loch Bealach Mhic Neill the laccolitic habit breaks down; and beyond this to the north and north-west only isolated masses occur, mostly breaking abruptly through the Torridonian rocks. On the west side of the area the belt of eucrite has probably been continuous; but it has been partly destroyed by the later intrusion of granite in the manner to be noticed below. The narrow and discontinuous strips which are exposed pass beneath the ultrabasic rocks to the east. (See fig. 23.) The belt expands in the lower part of Gleann Duibhal and about Harris. Here banding is often very apparent, its inclination being at very low angles. Between Abhuinn Fiadh-innis and Inbhir Ciell the ultrabasic rocks come to the coast; but the eucrite group reappears at the latter place, and makes some little spread about Papadil.

All these occurrences with a general stratiform habit may be regarded as parts of one large complex laccolitic body, having a diameter of not less than five miles. In addition, rocks belonging to this group break abruptly through the ultrabasic complex at numerous places in the interior of the tract. A small intrusion of this transgressive habit makes the hill An Dornabac, about a mile north-east of Harris (fig. 20). A large mass occupies a considerable area in the lower part of Glen Harris and on the higher ground to the west of Trallval. Here the relations between the eucrite and the peridotite are of an extraordinarily intricate kind (See Pl. II.) Not only does the newer rock near its border vein the older and enclose fragments of it to make a typical intrusion-breccia; but throughout the interior of the eucrite, over a breadth of 800 yards, there are abundant inclusions of peridotite, from small pieces to patches 200 yards long, all traversed by a network of eucrite veins.

The basic, like the ultrabasic, plutonic rocks of Rum are found not only in one continuous complex body, but also in the form of numerous small masses breaking through the Torridonian strata outside the mountain-tract. Some forty-five distinct intrusions were mapped, varying in dimensions from 20 to 750 yards. Most of them have an abruptly transgressive relation to the bedded rocks, and they may be regarded as small "bosses," or, since the form is often elongated, as short stout dykes. The direction of elongation usually approximates to N.N.W.-S.S E., and an oval drawn on the map to enclose all the occurrences has its long axis in the

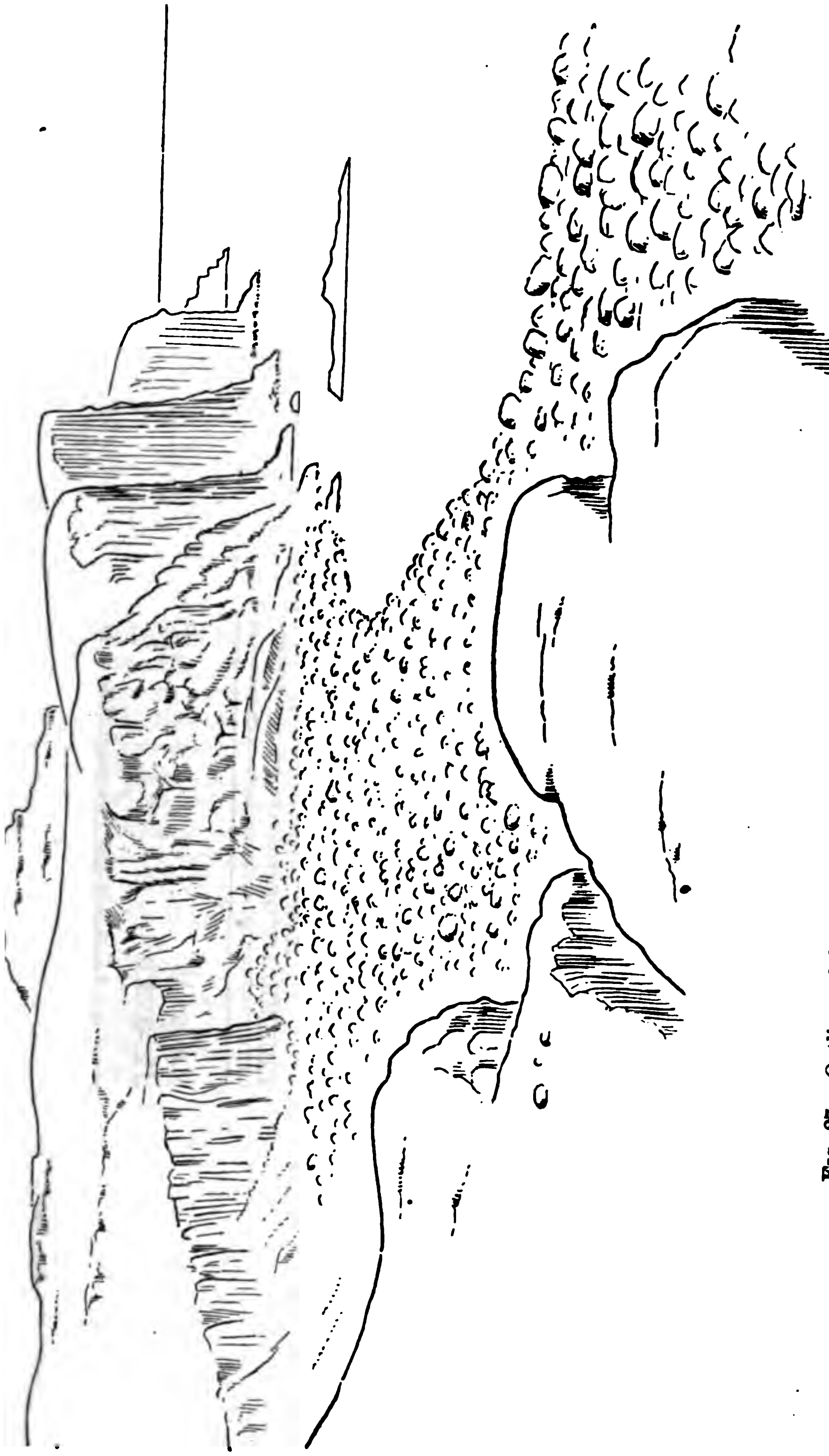

FIG. 27.—Outlines of the gabbro cliffs on the east side of Camas Mòr, Isle of Muck.

same direction. The same law has already been noted in the case of the small peridotite intrusions, though in the present case the area of distribution is somewhat wider. (See fig. 24 above.) The largest of the small plutonic masses are found near the long axis of the oval, while on the north-eastern side of the island there is a strip one to 1½ mile in width in which such intrusions are wholly wanting.

As regards the distribution of eucrites and gabbros respectively in Rum, it is certain that the latter play only a subordinate part. The thick stratiform complex which underlies the eastern mountains of Rum is essentially of eucrite, though it includes some sheets of the nature of gabbro. The basic rocks of the Harris district are also eucrites, and the same is true of the more irregular mass which disrupts the peridotites in Glen Harris and about Trallval. Some smaller intrusions within the mountain-tract are also of the eucrite type; notably a number of obliquely intruded dyke-like masses on the ridge connecting Allival with Barkeval. The small masses about Loch Bealach Mhic Neill and on the slope down into Kinloch Glen, lying on the border of the mountain-tract, are, on the other hand, of gabbro; and the scattered intrusions which break through the Torridonian to the north and north-west are, at least in general, of the same nature.

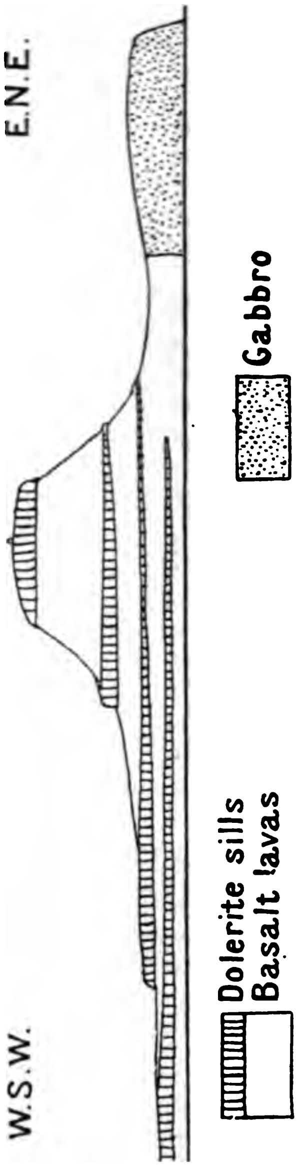

FIG. 27A.—Section through An Leachdach and Fionn-ard, Isle of Muck. Scale, 24 inches to a mile. Showing the dyke-like habit of the gabbro intrusion and the dying-out of the dolerite sills in the belt of metamorphosed basalts.

The only occurrence of a plutonic intrusion in the Small Isles outside Rum is in the *Isle of Muck*, and it appears to have escaped the notice of former observers. The rock is a *gabbro*. It forms a bold range of cliffs along the eastern side of Camas Mòr (fig. 27), where it makes an elongated strip; and, after an interruption, it appears again on the prolongation of the same line towards the farmhouse at Gallanach. Its breadth does not exceed 100 yards, and the general habit is that of a large dyke. Disregarding the break of continuity, the extent is more than 1¼ mile, and its direction agrees with that of the numerous smaller basic dykes of the island (N.N.W.–S.S.E.). Nevertheless, it is clear that this gabbro belongs to the plutonic phase, and occupies the same place in the igneous sequence as the gabbros of Skye and Rum. Besides disturbing and greatly metamorphosing the Jurassic strata on the shore, the intrusion has produced noteworthy alteration in the adjacent basaltic lavas. These have become sufficiently indurated to resist the intrusion of the dolerite sills at a later epoch, so that the sills all die out before reaching the gabbro (fig. 27A).

(ii.) PETROGRAPHY OF THE EUCRITES AND GABBROS.

In describing the basic plutonic rocks, we shall distinguish between eucrites and gabbros. The *eucrites* are crystalline rocks of medium to rather coarse grain. The striated felspar, the pyroxene, and often the olivine are apparent to the eye, and it is seen that there is some variation in the relative proportions of these principal constituent minerals. The range of variation is, however, much less than in the ultrabasic group.

The specific gravity of the rocks is high. A dark variety from the west side of Allt na Ciell, near Papadil, gave 3·06, and a more felspathic variety, taken N.N.E. of Loch Fiadh-innis, gave 3·03. Lower figures are found for rocks which depart somewhat from the normal type. The rock next mentioned, for example, gave 2·95 to 2·97. The eucrites are, for the most part, in a fresh condition.

Dr. Pollard has made a complete *chemical analysis* of one example of the Rum eucrites, but the rock selected is not perfectly typical of the group. The result is given in Column I., and corresponds roughly with the following mineral composition :—

Felspar, ...	48
Pyroxenes, ...	40
Olivine, ...	9
Iron-ores, ...	3
	100

The felspar seems to have about the composition of a variety of bytownite (Ab_1An_8). The rock does not differ much in bulk-composition from some of the Skye gabbros, as represented by analysis B. Of other British Tertiary districts, the only one from which eucrites proper have been described is that of Carlingford, where the felspathic constituent varies between anorthite and bytownite. The example of which an analysis is quoted in Column A is very rich in pure anorthite.

As seen in thin slices, the *felspars* of the eucrites proper give the extinction angles of anorthite or a variety approximating to this, and determinations of specific gravity by means of Sollas' diffusion column confirm this identification. The crystals, however, often show a marked zonary banding between crossed nicols. Carlsbad and albite twinning are universal, and a few pericline lamellæ are often seen in addition.

Most of the eucrites contain both a rhombic and a monoclinic pyroxene, the former being often as abundant as the latter (fig. 28, A).

	I.	A.	B.
SiO_2 - -	48·05	47·52	47·28
TiO_2 - -	0·49	...	0·28
Al_2O_3 - -	15·35	28·56	21·11
Cr_2O_3 - -	0·14	...	...
Fe_2O_3 - -	1·86	not det.	3·52
FeO - -	7·53	7·23	3·91
MnO -	0·28	...	0·15
(Co, Ni) O - -	0·11	...	...
CuO - -	0·05	...	...
MgO - -	12·53	1·48	8·06
CaO - -	11·02	15·44	13·42
Na_2O - -	1·26	...	1·52
K_2O - -	0·19	...	0·29
H_2O above 105° -	0·45	...	0·53
at 105° C. -	0·15	...	0·13
S - - -	0·20	...	...
CO_2 - -	0·44	...	...
	100·10	100·23	100·20
S. calc. as FeS_2 -	0·38	...	...
Spec. gravity -	2·95	2·757	2·90

I. [10,471].—Eucrite, near bend of Allt Mòr na h-Uamha, 1200 yards north-east of summit of Allival. Abundant ferriferous olivine, hypersthene, augite, and bytownite, with some chrome-magnetite: anal. W. Pollard, *Summary of Progress of the Geological Survey* for 1903, p. 56.

A.—Eucrite, Grange Irish [Barnavave], Carlingford: anal. S. Haughton, *Quart. Journ. Geol. Soc.*, vol. xii., p. 197 (1856).

B.—Olivine-Gabbro, Coir' a Mhadaidh, Cuillin Hills, Skye: anal. W. Pollard, *Summary of Progress of the Geological Survey* for 1899, p. 174.

It is of much less common occurrence in the rocks which fall more properly under the head of gabbro. The characteristic pleochroism, reddish to pale green, is usually more or less marked, and the mineral may accordingly be named *hypersthene* or bronzite. As a rule, no "schiller" structure is to be observed. Exceptionally there is a nearly colourless enstatite (in thin slices) with a marked longitudinal lamellar structure, and this variety may occur in the same rock with the ordinary hypersthene [10,987].

The *monoclinic pyroxene* is of a pale yellowish or brownish colour in thin slices. It very frequently shows structures of the "schiller" kind, parallel either to the orthopinacoid (diallage structure) or to the base (salite structure); and both may occur in the same crystal.

Olivine is not invariably present, but is very general, and occurs in larger amount than in the Skye gabbros. It is usually fresh, and may often be recognised by its yellow colour on a hand-specimen. The dendritic inclusions of magnetite so general in the ultrabasic group are less frequently found here, though they are sometimes well developed [10,506]. Secondary magnetite dust, representing the first stage of alteration of the olivine, is found separating along the cracks, which have not the parallelism of a regular cleavage.

Magnetite is invariably present in the eucrites, but not always in the gabbros. It is, no doubt, in part of a chromiferous variety, as indicated by the small content of chromic oxide in the rock-analysis cited above. The only other normal constituents in the rocks of this group are biotite and brown hornblende, which are not infrequently to be detected in the slices in rare and small patches. In the eucrites of some places, however, and especially about Bealach an Oir, between Glen Harris and Glen Dibidil, biotite occurs more plentifully, and is very noticeable on the hand-specimens. The absence of apatite in all these rocks is worthy of remark.

Varieties of the rocks arise from differences in the nature of the felspar and of the pyroxene, and also from different proportions of the essential minerals. Some of the eucrites are very rich in felspar, like the Carlingford rock analysed by Haughton (A on p. 98). When this type has olivine abundant and preponderant over pyroxene, it approaches the characters of allivalite. The commoner varieties have abundant hypersthene and augite. The texture and micro-structure of the rocks also show some differences. Even-grained varieties of medium coarseness are the most prevalent, but it is not uncommon for part of the augite to be developed in rather large ragged crystal-plates, which may impart something of a porphyritic aspect. In a few places, as in the cliff near the Mausoleum at Harris, the eucrite assumes a very coarse pegmatoid character, which follows certain bands a foot or two in thickness.

In thin slices it is seen that the order of crystallisation of the minerals is variable. In the typical eucrites the felspar is often idiomorphic not only to the augite but also to the olivine, and exceptionally the olivine builds ophitic plates enclosing numerous crystals of felspar (fig. 28, B). The rhombic pyroxene is generally in distinct idiomorphic crystals, and these sometimes tend to cluster round olivine [10,471].

Near the subsequently intruded granite the eucrite is often *metamorphosed.* To this cause we may probably attribute the uralitisation of the augite in some localities [10,989]. This mineral is largely converted to fibrous uralite and aggregates of green actinolite rods. Where there has been an actual impregnation with the acid magma, more important changes have been set up.

Quartz and orthoclase are introduced into the rock, and there is often a production of biotite and brown hornblende on a small scale by reaction between the pyroxene and the acid magma [10,726]. Similar phenomena have been described by Professor Sollas in the Carlingford district.* In Rum admixture of the eucrite with the granite-magma has given rise, as will be shown, to still more remarkable effects.

The *gabbros* are not always distinguishable in hand-specimens from the eucrites. In general they are not quite so fresh: a fact probably attributable to their occurrence on lower ground and in small masses with abruptly transgressive relations. We possess no complete analyses of the gabbros of the Small Isles, but Dr. Pollard has determined, as follows, the percentages of silica and the alkalies in two examples:—

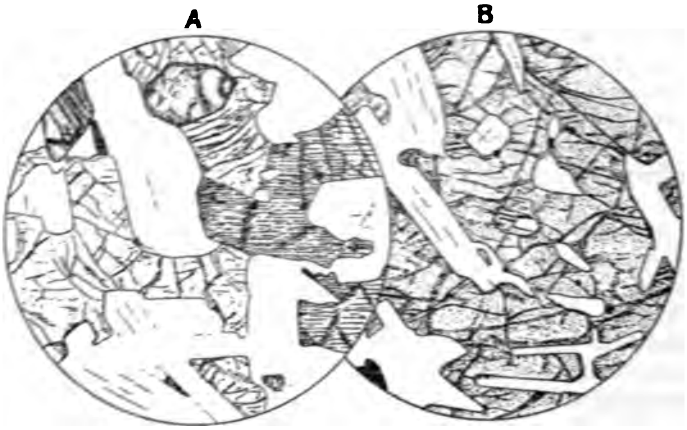

FIG. 28.—Eucrites, Rum; × 20.

A. [10,471].—Allt Mòr na h-Uamha; showing hypersthene (left) and diallagic augite (right), both enwrapping the felspar and olivine.

B. [10,990].—Leac a' Chaisteil; showing an ophitic plate of olivine enclosing numerous felspar crystals.

	II.	III.	I.
SiO_2 - -	47·78	46·09	48·05
Na_2O - -	2·80	3·01	1·26
K_2O - -	0·33	0·41	0·19

II. [11,728].—Gabbro, small boss on south side of Glen Kinloch, Rum. Consists of labradorite, augite, and magnetite, with pseudomorphs after olivine.

III. [11,729].—Gabbro, cliff east of Camas Mòr, Muck. Felspar is abundant, and has the properties of labradorite: the other constituents are olivine, magnetite, and augite.

I. [10,471]. Eucrite; analysis repeated for comparison.

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* *Trans. Roy. Ir. Acad.*, vol. xxx., pp. 477–512, pls. xxvi., xxvii. (1894).

These gabbros differ both from the eucrites and (in less degree) from the gabbros of Skye in their relative richness in alkalies. It may be remarked that such differences in silica-percentage as are found between these various basic plutonic rocks are without significance.

Mineralogically, the gabbros differ from the eucrites chiefly in the nature of their felspathic constituent, which is always *labradorite.* The crystals, however, sometimes have a zonary structure, the marginal part being less basic than the interior. Thus, in a slice [11,728] of one of the rocks mentioned above, a crystal cut parallel to the brachypinacoid gives for extinction-angles measured from the trace of the basal cleavage—

Centre, 24°, indicating labradorite, Ab_3An_5;
Margin, 9°, indicating andesine, Ab_4An_3.

In general the felspar is a medium labradorite, the maximum extinction-angle from the albite twin-line in symmetrically cut crystals being, in different rocks, 30°, 33°, 38°, &c.

Another distinctive character of the gabbros, as compared with the eucrites, is that a rhombic pyroxene is only exceptionally present. It has been noticed only in gabbros intimately associated with the eucrite complex, and perhaps to be regarded as aberrant members of that group. Olivine occurs in all the specimens examined, and is fairly abundant. It is usually of early crystallisation. When, however, the felspar is in very preponderant amount, as in the gabbro of Muck, it is idiomorphic, not only towards the augite, but towards the olivine and magnetite also.

CHAPTER IX.

Plutonic Rocks: Acid and Hybrid (Rum).

(i.) DISTRIBUTION AND CHARACTERS OF THE GRANITE GROUP.

The principal area of granite exposed on Rum is in the western part of the island, and has a roughly triangular shape on the map. Its south-eastern side is the coast-line from the headland of A' Bhrideanach to Harris, a distance of four miles. Here is a range of steep cliffs, 500 to 600 feet in height, showing in many places a very regular vertical columnar jointing. To the east or south-east the granite passes under the earlier plutonic rocks—eucrite, harrisite, and peridotite. (See fig. 23.) Along the irregularly curving northern boundary the granite is in most places in contact with the Torridonian sandstone. The surface of junction is usually steep, but on the whole the granite overlies the sandstone (fig. 29). Regarding the large intrusive mass as of generally laccolitic habit, this northern boundary thus represents the base. The thickest part of the laccolite is where it is cut by the coast-line; and on the lower slopes of Minishal, at the north-east angle of the triangle, we see the dying-out of the laccolite in this direction. This granitic tract includes Orval (1869 feet), Beinn a' Bhàrr-shaibh (1816), and Sròn an t-Saighdeir (1706), with lower hills, the ground being steep in places, but having usually the smooth rounded outlines so characteristic of granite in the Inner Hebrides (fig. 17, above).

Granite appears again, though in no great force, to the east of the artificial cut by which the water of Loch Sgathaig has been diverted northward. The mass is of very irregular shape, breaking through peridotite and eucrite, and it graduates into banded gneiss.

The remaining occurrence of granite is on the lower south-western slope of Sgùrr nan Gillean, towards Papadil. It is in a complicated and much-disturbed district, and is intruded, like the mass just noticed, nearly on the horizon of the main overthrust. Both northward and eastward it passes into well-banded gneiss.

Petrographically, the rocks of this group have nothing to distinguish them from the corresponding rocks in Skye, and therefore do not demand any detailed description. They fall into the less acid of the two sub-groups which may be recognised among the British Tertiary granites, being comparable with the prevalent types in Skye, Mull, and the Carlingford district, as distinguished from those of St. Kilda, Arran, and the Mourne Mountains.*

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* *Tertiary Igneous Rocks of Skye*, p. 153 (1904).

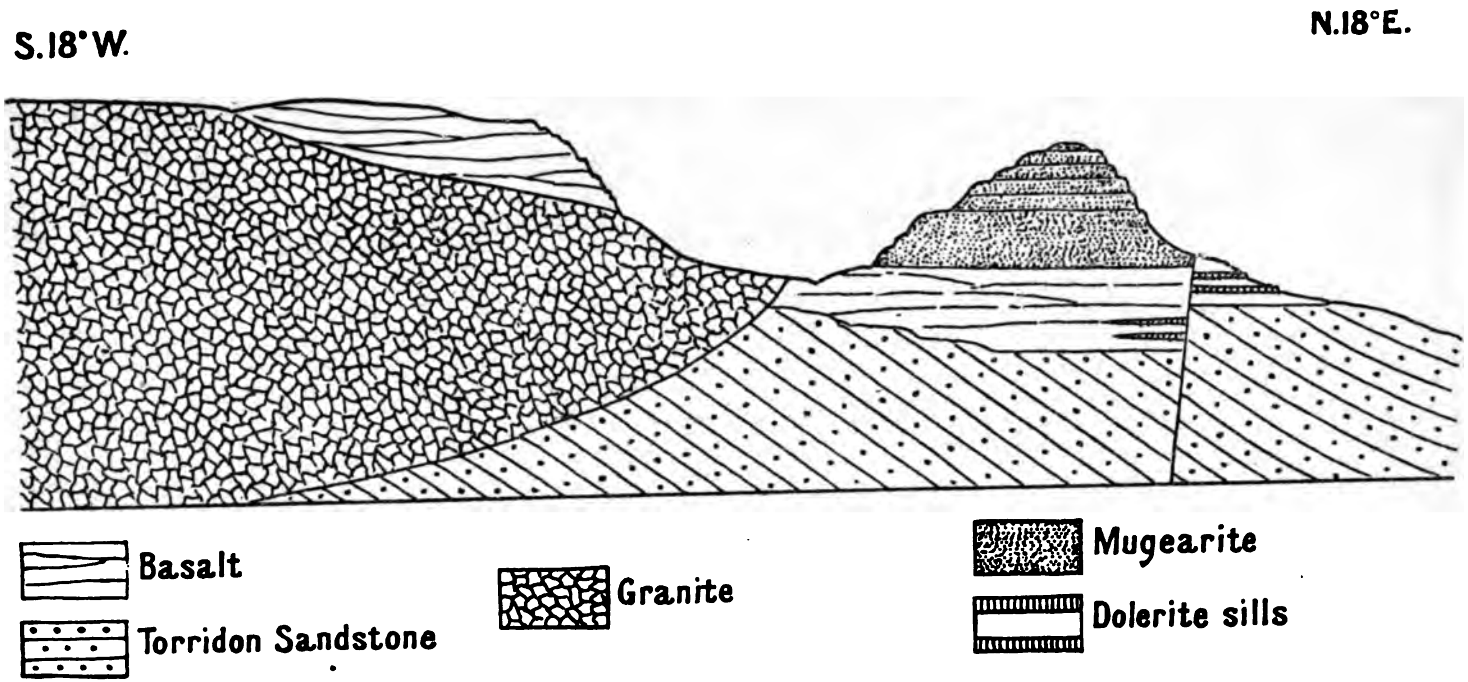

FIG. 29.—Section through Orval and Fionn-Chrò, Rum. Scale, six inches to a mile.

The usual ferro-magnesian element is hornblende, showing green to greenish-brown colours in thin slices; but an augite of the malacolite kind is not infrequently present in subordinate amount. Magnetite and some apatite occur as accessory constituents. The rest of the rock consists of felspars and quartz, usually more or less regularly intergrown in micrographic fashion. Part of the felspar is usually in the form of rectangular crystals; but these are bordered, and sometimes invaded in their marginal parts, by the micropegmatite intergrowth. Orthoclase is the dominant felspar, but oligoclase is constantly present in addition. The rocks may thus be termed hornblende-granophyres. A specimen from north-east of Loch Papadil gave the specific granity 2·61.

The foregoing characterisation applies to what we may call the normal rocks of this group, and these present little variety of an essential kind. Only towards the margin of the intrusive masses, where they are contiguous with eucrite or peridotite, do we find certain peculiarities which we may regard as abnormal. There can be no doubt that these peculiarities, in particular the coming in of hypersthene and biotite, are due to the granite magma having enclosed and dissolved basic material derived from the neighbouring rocks. The subject is worthy of a more particular notice.

It may be recalled that the granites (as also the gabbros) of Skye have been proved by Professor Tilden[*] to contain a noteworthy amount of free gases, chiefly hydrogen and carbon dioxide. It is probable that the similar rocks of Rum would yield like results, but this has not been tested. We may note, however, another interesting investigation relating to the occurrence of *radium* in our rocks. The Hon. R. J. Strutt[†] has demonstrated the presence of this substance in a large number of igneous rocks, and estimated its amount. He has shown that, as a rule, acid rocks are richer in radium than basic. The following are his results for some British Tertiary igneous rocks, the figure given in each case being the percentage of radium multiplied by 10^{10}:—

Pitchstone dyke, Rudh' an Tancaird, Eigg,	2·06
Peridotite, summit of Ruinseval, Rum,	1·37
Olivine-Basalt lava, Talisker, Skye,	1·32
Olivine-Eucrite, Rum (rock analysed, p. 98),	1·28
Olivine-Dolerite sill, Tarbert, Canna,	1·24
[Do. ?] Basalt, Giant's Causeway, Antrim,	1·03
Granite, north-east of Loch Papadil, Rum,	0·723
Foliated Olivine-rock, Fiadh-innis, Rum,	0·676
Dunite, near Loch Scavaig, Skye,	0·664

The content of radium here shown is low as compared with that of most other rocks, and this is especially so in the case of the granite. The granites examined from other localities all gave higher figures, ranging up to 9·56. These were Palæozoic rocks, and it may be conjectured that the relative poverty in radium of the granite of Rum is related to its geological age.

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[*] *Proc. Roy. Soc.*, vol. lx., pp. 453–457 (1897). *Chem. News*, vol. lxxv., pp. 169, 170 (1897).

[†] *Proc. Roy. Soc.* (A) vol. lxxvii., pp. 472–485 (1906).

(ii.) HYBRID ROCKS, INCLUDING GNEISSES.

The special interest attaching to the granite of Rum arises from its relations with the basic rocks, which it followed probably after no long interval. Owing to the manner in which the various plutonic rocks have been intruded, the newer being in general forced in immediately below the older and encroaching upon it, the granite is, as a rule, in contact with the eucrite. Between these two rocks hybrid products have been formed by the acid one invading the basic, and by partial intermingling of the two the gneisses to be described have in the main been constructed. It is possible that in some places the peridotites have also contributed in a less degree.

Along the eastern border of the main granite tract the acid magma has so energetically attacked the eucrite, that what was probably a continuous though narrow belt of that rock has been destroyed along most of the line; and here the phenomena of *intimate admixture and hybridism* may be studied without the further complication of gneissic banding. The junction of the two rocks is seen in the bold sea-cliffs near the Mausoleum at Harris, and here it may be observed how the basic rock is shot through by innumerable slender veins and threads from the later intrusion, while the acid rock contains dark patches and spots which represent partially digested fragments or xenoliths picked up from its neighbour. Closer examination shows that both rocks are also modified in the composition of their substance, the one being acidified and the other basified in a certain degree. Farther north, where the boundary crosses the valley of Abhuinn Monadh Mhiltich similar effects are displayed on a more striking scale. Here there is a zone of visible admixture, at one place nearly 50 yards wide, consisting of a kind of *intrusion-breccia* of dark fragments set in a light matrix. According as one or the other rock predominates, the admixture may be regarded as a network of veins of the later rock traversing the earlier or a crowd of fragments of the earlier enclosed in the later. At intermediate points along the boundary-line a similar igneous breccia is frequently seen; and where it fails, the reason is that more advanced reactions have given rise to hybrid rocks of which the dual origin is no longer easily visible to the eye. In particular, the dissolution of a quantity of ultrabasic rock in the acid magma has given rise to a granite or granophyre containing hypersthene, a mineral foreign to the normal acid rocks of this region; and in places a pale rock with distinct dark spots is seen to graduate, by the disappearance of the spots, into a hypersthene-bearing granite (Pl. VII., fig. 1).

The *gneisses* of Rum, though not covering any large area of ground, are developed on a scale sufficient to display their characteristic features, which closely resemble those of the

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Lewisian formation; while at the same time their relation to normal plutonic rocks, and the actual processes by which they have originated, are matters of direct observation on the ground. The most considerable area of gneiss occupies the upper part of Fiadh-innis (known as Sandy Corrie), and extends to a considerable height up the western slopes of Ashval and Sgùrr nan Gillean. having a width of about half a mile. It is further prolonged round the southern side of Sgùrr nan Gillean and eastward to the coast at Dibidil, being here a narrower and less continuous belt. There are also some smaller scattered intrusions of gneiss in the Dibidil neighbourhood, not visibly connected with the larger area. Gneiss is seen again in the centre of the island, intricately associated with normal plutonic rocks, to the east and north of Loch Sgathaig (the Long Loch). Finally, a patch a quarter of a mile long forms the summit and part of the south-easterly face of Beinn a' Bhàrr-shaibh, within the main granite tract of the west.

The relations are most clearly exhibited in the largest area, in Fiadh-innis.* (See map, Pl. II.)

Here, along the northern and western border of the gneiss, is a strip of eucrite, which must be the attenuated relic of a more considerable mass. It has been invaded by the acid magma in an intricate network of veins, and its substance has been in places more intimately permeated, so that it has suffered a certain degree of acidification. What is seen along this bordering strip affords visible illustration of the manner in which a great part of the original mass of eucrite has been destroyed. Indeed the process of destruction can be traced step by step. Detached portions of eucrite, up to 50 yards in length, with similar veining and permeation, lie in the gneiss; and smaller blocks are seen in every stage of dissolution, being traceable finally into the dark streaks of the gneiss itself, the significance of which is thus conclusively demonstrated. These phenomena may be studied in ample variety in the northern part of this gneiss area, to distances of about 200 yards from the margin. Beyond this the earlier stages, which furnish the clue to the origin of the gneiss, are scarcely to be observed.

The gneissic rocks in Fiadh-innis (and elsewhere, with an exception to be noted below) neither in the field nor under the microscope show any sign of crushing, such as would ensue from deformation of the solid rocks, and it is quite clear that the differential movement to which the gneissic structure is due was a contemporaneous movement. It is equally clear, however, that the banding is not a mere flow-structure connected with a stratiform habit of intrusion, as in the ultrabasic group and the eucrites. Throughout this principal area the structure has a prevalent high inclination, often near the vertical. The general strike of the banding is east–west, but with some deviations. In the northern part of the area it is rather E.S.E.-W.N.W., and the usually high dip (to S.S.E.) sometimes diminishes to 20° or 30°. In the south again there are low dips in places, directed here to some point of north. It is specially noteworthy that the banding is not parallel to the boundaries of the gneiss, but has its direction determined by some independent and larger law. This is the case even in tongues and veins a few inches wide penetrating the eucrite.

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This tract of gneiss, measuring about a mile by half a mile, and with continuous exposures of bare rock, thus affords a very complete picture of the manner of origin of this interesting group. The gneiss is an intrusive igneous rock, belonging to the Tertiary series and younger than the eucrite. The gneissic banding is due to the drawing out by *differential movement* of a heterogeneous rock-complex; and the heterogeneity arose, not as in the peridotite-allivalite-group from incomplete segregation, but from incomplete admixture, the elements being the solid eucrite and the acid magma which invaded that rock. The deformation of which the banding gives evidence affected the heterogeneous mass while still partially fluid or mobile; and it was not an ordinary flow-structure, but was related to differential crust-movements belonging to this late epoch of the plutonic phase of activity.

The smaller areas of gneiss in other parts of Rum afford confirmatory and supplementary evidence of the explanation which has been briefly set forth. The patch on Beinn a' Bhàrr-shaibh is instructive. It occurs in the principal granitic tract of the west; and the fact that the gneiss here passes continuously into the granite below shows that the acid magma which furnished the most important element of the gneiss is the same that, in its pure state, is represented by the normal granite of the island. This patch, as seen on the map, is situated within the granite tract, but it is really an outlier of the granite margin. Prior to erosion the overlying eucrite extended westward of its present line of outcrop, and the summit of the hill only just misses the base of the eucrite laccolite. The gneiss of Beinn a' Bhàrr-shaibh is thus the equivalent of the zone of intrusion-breccia already mentioned, the relations being as shown in the section (fig. 30). The proof of this is that a little way off the line of the section the intrusion-breccia passes for a short distance into gneiss, while the eucrite itself, which along this part of the line is often wholly destroyed, also appears as a narrow strip. In this place then the gneiss appears as a junction-phenomenon between the eucrite and the granite. Whether at any part of the zone of intermixture we find gneiss or only intrusion-breccia, depends on the amount of contemporaneous shearing or traction at that place.

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We have already seen from the extreme disturbance, violent contortion, and rapid variation of strike of the Torridonian rocks in this neighbourhood, as well as from the great development of crush-breccias, that the Palæozoic overthrusting reached here its greatest intensity. The sharp undulations of the surface of overthrust on Beinn nan Stac (fig. 5) seem to indicate further that the movement was prolonged somewhat later here than elsewhere. It appears that the same is true of the much less intense crust-movements of Tertiary age with which the banding of the gneiss is connected. Starting from Fiadh-innis, an irregular and interrupted belt of gneiss extends over Leac a' Chaisteil, along the southerly slope of Sgùrr nan Gillean, and eastward to the sea at Dibidil, following pretty closely the line of the old overthrust. This gneiss is in most respects like that in other parts of the island. It passes in the direction of Papadil into a normal granite. An interesting patch some 400 yards long along the lower part of the Dibidil River is in part bordered by narrow strips of eucrite, the gneiss sending veins into the basic rock and enclosing detached blocks of it. The banding in this district is almost always vertical, or nearly so, and about Dibidil it shows great and rapid variation in strike, indicating a greater local disturbance here than in other localities. Moreover, disturbance was prolonged or renewed in this district after the gneiss had become a solid rock. The proof of this is seen in a *crush-brecciation of Tertiary age* posterior to and affecting the gneiss itself. For a length of about half a mile on the south-westerly slope of Sgùrr nan Gillean the gneiss passes into a thoroughly brecciated state. Fragments of hornblendic and other varieties are crowded together without any common direction of their well-marked banding. A certain amount of interstitial matrix seems to be of the nature of an igneous injection, which would imply that intrusion had not wholly ceased when the rock was shattered. The crushing was not wholly restricted to the horizon of the gneiss. The old crush-breccia immediately above contains near the junction abundant fragments of gneiss mingled with the predominant sandstone, and the same thing is seen at many places eastward to Dibidil.* A notable proportion of gneiss fragments is sometimes present in the sandstone-breccia at considerable distances from any body of gneiss in place, a result doubtless due to the breaking up of irregular offshoots from the main mass. The junction of the gneiss with the crush-breccia (of Torridonian material) is, apart from later crushing, of a more intimate kind on the slopes of Sgùrr nan Gillean than elsewhere, the magma sometimes forcing its way in between the component fragments of the breccia, and detached fragments from the latter becoming enclosed in the gneiss. It is doubtless by the breaking up of a mass like this that the composite breccia, with gneiss fragments, has been produced. In the main body of the gneiss itself between Leac a' Chaisteil and Beinn nan Stac cataclastic effects on a large or a small scale may constantly be detected.

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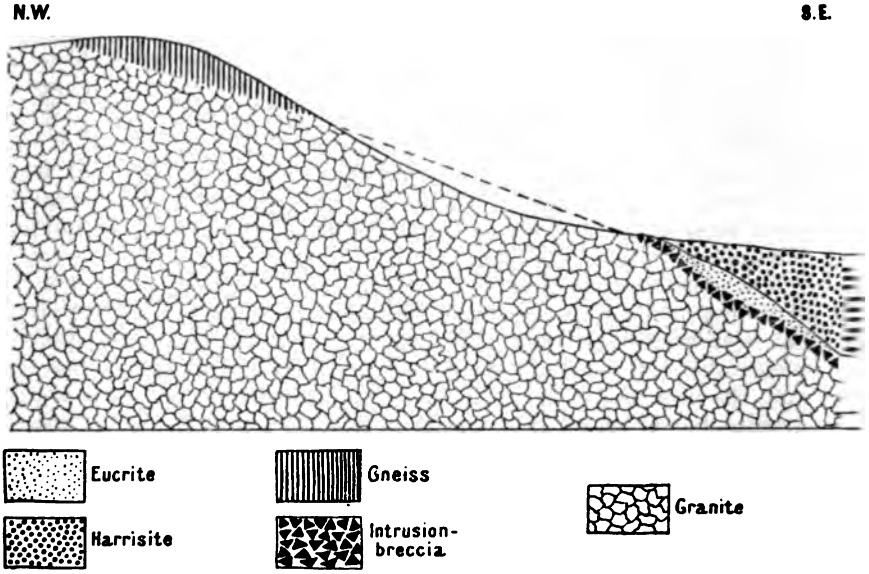

FIG. 30.—Section through Beinn a' Bhàrr-shaibh, Isle of Rum. Scale, six inches to a mile. Illustrating the relations of the gneiss to the eucrite and granite.

It is very noticeable that the several occurrences of Tertiary gneiss in Rum are found in general near the horizon of the Palæozoic overthrusting. This lends some colour to the supposition that the Tertiary crust-movements, with which the gneissic banding is bound up, followed somewhat similar lines to those of much earlier date and much greater intensity which affected so profoundly the old sedimentary foundation of Rum. More significant observations bearing on this point emerge from an examination of the gneisses of the Sgùrr nan Gillean and Dibidil district.

We have already seen from the extreme disturbance, violent contortion, and rapid variation of strike of the Torridonian rocks in this neighbourhood, as well as from the great development of crush-breccias, that the Palæozoic overthrusting reached here its greatest intensity. The sharp undulations of the surface of overthrust on Beinn nan Stac (fig. 5) seem to indicate further that the movement was prolonged somewhat later here than elsewhere. It appears that the same is true of the much less intense crust-movements of Tertiary age with which the banding of the gneiss is connected. Starting from Fiadh-innis, an irregular and interrupted belt of gneiss extends over Leac a' Chaisteil, along the southerly slope of Sgùrr nan Gillean, and eastward to the sea at Dibidil, following pretty closely the line of the old overthrust. This gneiss is in most respects like that in other parts of the island. It passes in the direction of Papadil into a normal granite. An interesting patch some 400 yards long along the lower part of the Dibidil River is in part bordered by narrow strips of eucrite, the gneiss sending veins into the basic rock and enclosing detached blocks of it. The banding in this district is almost always vertical, or nearly so, and about Dibidil it shows great and rapid variation in strike, indicating a greater local disturbance here than in other localities. Moreover, disturbance was prolonged or renewed in this district after the gneiss had become a solid rock. The proof of this is seen in a *crush-brecciation of Tertiary age* posterior to and affecting the gneiss itself. For a length of about half a mile on the south-westerly slope of Sgùrr nan Gillean the gneiss passes into a thoroughly brecciated state. Fragments of hornblendic and other varieties are crowded together without any common direction of their well-marked banding. A certain amount of interstitial matrix seems to be of the nature of an igneous injection, which would imply that intrusion had not wholly ceased when the rock was shattered. The crushing was not wholly restricted to the horizon of the gneiss. The old crush-breccia immediately above contains near the junction abundant fragments of gneiss mingled with the predominant sandstone, and the same thing is seen at many places eastward to Dibidil.* A notable proportion of gneiss fragments is sometimes present in the sandstone-breccia at considerable distances from any body of gneiss in place, a result doubtless due to the breaking up of irregular offshoots from the main mass. The junction of the gneiss with the crush-breccia (of Torridonian material) is, apart from later crushing, of a more intimate kind on the slopes of Sgùrr nan Gillean than elsewhere, the magma sometimes forcing its way in between the component fragments of the breccia, and detached fragments from the latter becoming enclosed in the gneiss. It is doubtless by the breaking up of a mass like this that the composite breccia, with gneiss fragments, has been produced. In the main body of the gneiss itself between Leac a' Chaisteil and Beinn nan Stac cataclastic effects on a large or a small scale may constantly be detected.

* See *Trans. Edin. Geol. Soc.*, vol. viii., pp. 344–350, pl. x. (map) (1905.)

The manner in which the Tertiary brecciation on Sgùrr nan Gillean has been localised at or near the horizon of the old crush-breccia is an interesting example of a newer movement following very closely the lines of an older. Judged by the distribution of its effects, the newer movement was of the same general type as the older, *i.e.*, it had a quasi-horizontal and unilateral character such as, if further developed, would have resulted in an overthrust. In this view it was quite distinct in its nature from the movement with which the gneissic banding was connected, which was clearly a quasi-vertical traction or shearing.

As regards this shearing movement, it is of interest to compare the directions of the banded structures in the several groups of plutonic rocks in Skye and Rum. In the ultrabasic group in both islands it is invariably found that all banded structures are parallel with the intruded sheets themselves, and the same is true of the eucrites of Rum. In the gabbros of the Cuillins* the banding is no longer parallel to the sheets, but dips at angles often about 45° towards the interior of the laccolite, as if indicating a certain shearing movement related to that centre, superposed upon the ordinary fluxional movement. The high dips prevalent in the gneisses of Rum point to a much more considerable shearing movement in a vertical sense; in this case not related apparently to the local centre but to some cause of a larger order.

The banded and foliated structures met with in various unaltered plutonic rocks in the Inner Hebrides are of interest to geologists, not only intrinsically, but as throwing light on the significance of like structures in some rocks of much greater geological antiquity. This is an aspect of the subject which cannot be discussed in this place. It was clearly appreciated by Macculloch, as appears from the following passage in his description of the "hypersthene-rock" (gabbro) of the Skye mountains:—"These several varieties are all irregularly mixed, occurring in close contact in the same continuous mass, occasionally passing into each other, and often disposed in such a tortuous manner as would arise from disturbing a mixture of different tenacious fluids. One rare variety yet remains especially deserving of notice. In this the crystals of hypersthene [augite] are in small compressed prisms, disposed with their flat surfaces parallel to each other and to the general plane of the mass, as mica is in gneiss, and producing the same fissile tendency. Like the mica in the trap of Kerrera and Seil, it may be supposed to throw doubts on the opinion that the fissile property of gneiss, or even of micaceous schist, is the result of mechanical deposition."† In 1893 Sir Archibald Geikie‡ urged the same consideration in more explicit terms; and in the following year he and Dr. Teall, in describing the banded structures of the Skye gabbros, instituted a parallel between these rocks and the Lewisian gneisses of the north-west of Scotland.§ The present writer has since shown that structures of this kind are more prevalent in the peridotite group of Skye than in the gabbros; and, as described in the foregoing pages, they are even more strikingly displayed in the ultrabasic group of the Rum mountains. In the hybrid gneisses described in the present chapter we find, however, a still closer resemblance to the Lewisian gneisses, a resemblance extending not only to structures but in great measure to mineralogical composition too.

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* *Tertiary Igneous Rocks of Skye*, pp. 90-93, with figs. 17, 18 (1904).

† *Description of Western Islands of Scotland*, vol. i., p. 390 (1819).

‡ *Rep. Brit. Assoc.* for 1893, pp. 754, 755 (1894).

§ *Quart. Journ. Geol. Soc.*, vol. l., pp. 657-659 (1894).

The gneisses of Rum vary in composition from acid rocks comparable with normal granites, though often distinguished by some special peculiarity such as the presence of hypersthene, to basic varieties very rich in hornblende. Banding, on a large and on a small scale, characterises the whole group in varying degree of development, being usually very conspicuous in the field. It is determined by alternations of more or less different varieties of rock, the more extreme types commonly occurring in the narrower bands. In short, the degree of development of the banded structure depends upon the amount of basic material incorporated in the acid magma in any given part. Banding fails only in some of the most acid portions of the complex, representing the nearly pure granite magma and often tending to assume a rather coarse and almost pegmatoid character. The more basic portions are invariably well banded, and in those which are richly hornblendic there is in addition a parallel orientation of the crystals which imparts a fissile character. The more acid varieties are, on the whole, the more abundant; but there are considerable stretches of ground along which the richly hornblendic gneisses prevail, usually with interbanding of the quartzo-felspathic. The chief difference between this group of gneisses and the Lewisian is seen in the comparative rarity in Rum of the more micaceous varieties; but it can scarcely be doubted that, if the granite magma had invaded and incorporated gabbros and diorites as well as eucrites and peridotites, biotite would have been a conspicuous product of the reactions. A coarse biotite-gneiss, interbanded with other varieties, is found in a few places, *e.g.*, to the north of Priomh-loch Mòr.

In the complex produced by the intermingling of granite with basic material (mainly eucrite) the two rocks have to a great extent lost their individual characters. Nevertheless, the dual origin of the complex is often broadly indicated on the ground, and in some places it would be possible to draw lines approximately dividing basified granite from acidified eucrite. The more acid portions, and indeed the greater part of the whole, must be regarded as coming from a granitic magma modified in varying degree by the inclusion of basic material, which was not merely mechanically picked up but more or less perfectly digested. On the other hand, there are belts of dark hornblendic gneiss, from a few feet to 50 yards in width, which are to be considered rather as sheets of eucrite transformed partly by metamorphism, but also by impregnation with the acid magma. The latter has penetrated the gabbro in a manner guided by the general stratiform arrangement, and has enveloped sheet-like portions of that rock which, though greatly disguised, are still sometimes recognisable as distinct rock-bodies.

The *petrography of the gneisses* does not need very detailed description. The interest here attaches chiefly to the phenomena of dissolution of "xenoliths" or inclusions of basic rock in the acid. The early stages of the process may be studied in the acid portions of the gneiss in many places, but also along the eastern border of the main granite tract, where, as we have seen, the "intrusion-breccia" is really the equivalent of the gneiss. The xenoliths usually show an advanced stage of replacement, resulting from interchange of substance between them and the enveloping magma. They thus come to be represented by casts or pseudomorphs, retaining their former outline, but consisting of a granular aggregate wholly of new formation, to which the granite magma has contributed. This replacement without obliteration of the outline is a familiar phenomenon in hybrid igneous rocks, and cannot well be reconciled with the doctrines of those petrologists who deny the importance of diffusion in igneous rock-magmas. The constitution of the replaced xenoliths varies according to the nature of the original enclosed fragment. Granules of pyroxene are often the most conspicuous element. They are partly of augite, but largely of hypersthene. These presumably come from eucrite fragments, containing originally both hypersthene and olivine which latter in presence of a magma with free silica will naturally react to produce a rhombic pyroxene. The reciprocal modification of the acid matrix, essentially an enrichment in the dioxide bases, shows itself in a somewhat diminished proportion of quartz and an increased amount of the ferro-magnesian silicates, lime-bearing felspars, and magnetite. Pyroxene granules may become detached from the xenoliths, but the form and size of the pyroxenes in the matrix often shows that they are not mechanically derived, but have crystallised from the somewhat basified granite magma (Pl. VII., fig. 1). It is noticeable that the latter, with any noteworthy amount of modification in composition, does not develope the micrographic structure so generally found in the normal granite. In other xenolithic rocks we find pyroxenes no longer an important element, their place being taken by green hornblende, brown mica, and magnetite. These minerals have been formed in abundance in the transformed xenoliths and in greater or less amount also in the modified acid matrix. The phenomena here are very like those observed in reactions between gabbro xenoliths and granite in Skye, and it must be supposed that the enclosed *débris* in such cases was gabbro rather than eucrite.

Those parts of the gneiss which illustrate the early stages of dissolution of basic xenoliths have no noteworthy banded structure, having escaped the shearing movement which has affected most parts of the complex. In some slices we can trace the breaking up of the transformed xenoliths, the aggregates becoming resolved into detached granules and incorporated in the general matrix. In the bulk of the gneiss all traces of the earlier stages of the process are obliterated. The drawing out of the hybrid rock, by setting up a banded structure, has often accentuated the composite nature of the mass; but it has at the same time obscured the exact mode of origin. Only by a comparative study is the evidence made complete.

Belts of richly hornblendic gneiss are to be ascribed, as already remarked, to the inclusion in the acid magma of sheet-formed masses of basic rock, which were apparently of the nature of eucrite. They have been greatly transformed, not merely by metamorphism but often by transfusion; and little, if anything, of their original material remains unaltered. They have now the general appearance of foliated diorites, a parallel orientation of the hornblende crystals being usually well marked. The texture is sometimes rather coarse, with crystals a quarter of an inch long. In thin slices the hornblende is of a deep green colour. In a general sense it doubtless represents the pyroxene of the original basic rock, and exceptionally a crystal of augite may be seen in process of conversion; but where crystal forms occur, they are those of the hornblende itself, and in general the mineral must be not merely pseudomorphic but crystallised from actual fusion of the eucrite or gabbro. The felspar includes more or less orthoclase in addition to the plagioclase, which in some cases is of a relatively acid variety. These peculiarities, with the occurrence of a certain amount of quartz and biotite, must be attributed to permeation by the acid magma (fig. 31, B). Where these peculiarities are

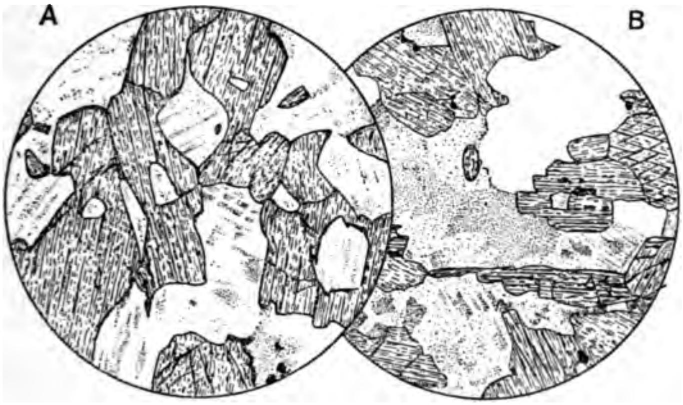

FIG. 31.—Hornblende Gneisses, Rum; × 20.

A.—North-east of Priomh-loch Mòr. This rock consists entirely of hornblende and a basic felspar, and probably results from the fusion and recrystallisation of a eucrite with little or no admixture of the acid magma.

B.—North of Priomh-loch Mòr. This is a hybrid rock, resulting from the admixture of eucrite and granite. It contains abundant quartz, and the felspar (turbid in the slice) is of less basic composition, probably including some orthoclase.

wanting, we may presume that the eucrite has been fused and recrystallised without any noteworthy addition of granitic magma (fig. 31, A).

In some places where the gneiss is in contact with the Torridonian rocks it encloses in its marginal parts highly metamorphosed fragments of sandstone and shale; but there is nothing to suggest that the sedimentary rocks have contributed in any sensible degree to the gneiss complex, which is wholly of igneous origin.

CHAPTER X.

Basic Sills.

(i.) GENERAL CHARACTERS OF THE DOLERITE SILLS.

Of the minor intrusions which followed the plutonic phase of activity, the most important are the sills of basic rocks which, as already remarked, alternate with the lava-flows of the plateau-hills.* These sills form a well marked *natural group*, developed throughout the whole of the basalt country, and not in any way related, as the plutonic rocks of Rum are, to a defined centre. Indeed we have seen that the sills die out as they approach the plutonic rocks, owing to their inability to penetrate the massive indurated basalts of the belt of metamorphism. This behaviour, besides other evidence, fixes the age of the sill-group as posterior to the plutonic phase of activity. It is, however, not long posterior, for the sills are clearly older than the majority of the basic dykes, and are also older than the minor intrusions of acid composition. The group in question represents then the earliest, as well as the most important, episode of the phase of minor intrusions.

The sills are not confined to the horizon of the basalt lavas, but occur also in the underlying Jurassic strata of Eigg. It is doubtful to what extent they are represented in the Torridonian tract of Rum. The massive and often coarse sandstones of this formation are not suited to the injection of regular sills. Sheet-formed intrusions of basic rocks are found in many parts of the sandstone tract, usually of small dimensions and often irregular in their behaviour. It is possible that some of these represent the great group of dolerite sills, modified in habit by the nature of the country-rock; but they may belong to later groups of intrusions. Probably the sill-group has a more or less defined lower limit of distribution, and it is noteworthy that it is quite wanting in the Torridonian shales. We may accordingly confine our attention to the sills in the Oolites and the Tertiary volcanic series. The important part which they play may be gathered from the sketch-map given below (fig. 48) of a typical portion of the plateau country.

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* It is not possible to represent the very numerous sills on a small-scale map. A sufficient number are shown to represent in a generalised manner the structure of the ground.

Both in the stratified rocks and in the basalt group the sills show in general a remarkably regular disposition, following the bedding-planes with considerable accuracy for long distances, and often maintaining a nearly uniform thickness. The largest sills are about 100 feet thick, the smallest only two or three feet. Their strong escarpments impart to the slopes of the plateau-hills a terraced appearance which is highly characteristic (figs. 16, 32). On a small scale too the junctions of the sills with the basaltic lavas are usually quite plane and smooth, minor irregularities being decidedly rare (fig. 33). Much more marked departures from the regular habit are found where a sill encounters a thick mass of coarse volcanic agglomerate or conglomerate. Here the sill may become irregularly entangled with the unstratified mass, as at Coroghon and Alman (Canna) (fig. 34), or it may be abruptly arrested, as already remarked at Dùn Beag, Sanday. (See fig. 12, above.)

Inland the sills give rise to flat-topped plateau-hills with strongly terraced slopes. In precipitous cliffs they do not make noticeable features; but on a shelving coast they may cause broad reefs. This is very noticeable in the case of Muck, where the arrangement is nearly horizontal. Neither this island nor its larger neighbour, Eigg, possesses any good harbour. Canna Harbour is a depression eroded in the volcanic

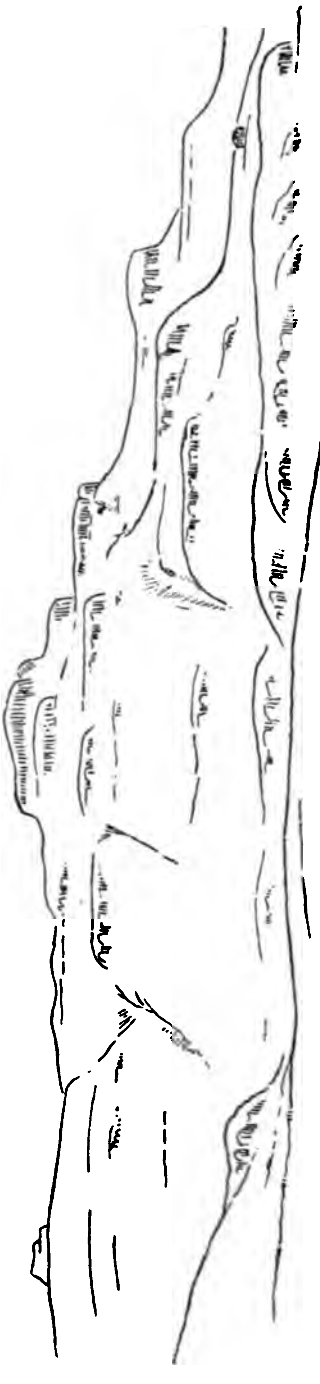

Fig. 32.—Outlines of hills in the eastern part of Canna; looking north-east from An Doirlinn. The strong escarpments are made by dolerite sills alternating with the basalts.

conglomerates, where regular sills are in general not a conspicuous feature, and the only other good anchorage in the Small Isles is that of Loch Scresort in the Torridonian tract of Rum.

A conspicuous feature of the dolerite sills of Canna is the prevalence of strongly-marked and often very regular *columnar jointing*. This was remarked long ago by Da Costa, Clarke, Jameson, and others. It is more striking here than in Skye, though the structure does not often present the perfection of development which has made Staffa and the Giant's Causeway famous. Some of the best examples may be examined along the south coast, eastward from Tarbert, where we may study the grouping of the columns in the face of the escarpment and their form in cross-section in the tidal platforms which fringe the shore. In the former kind of exposure we may see that a general parallel arrangement in a nearly vertical position is the rule where the structure is most perfectly developed. This is due to the tendency for the joints to be set perpendicularly to the bounding surface of the sill, as is clearly shown in places where this surface is for any reason curved or irregular, the columns curving in a corresponding manner. (Compare fig. 34.) The less perfect columns, often of smaller dimensions, may show varying inclinations or a tendency to sheaf-like divergence. Each individual column preserves the same form of cross-section throughout its length, and this length may be the whole thickness of the sill.

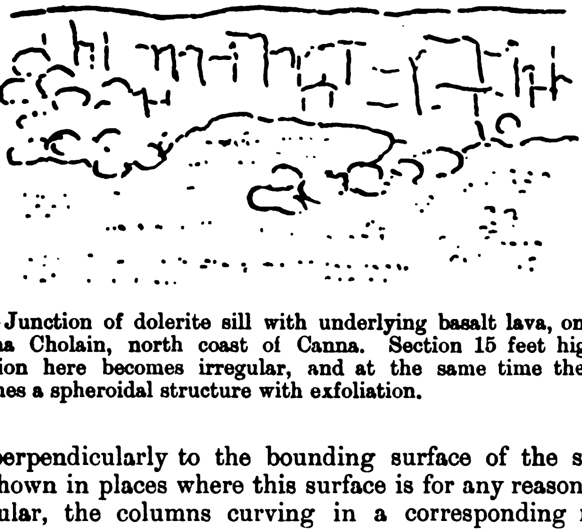

FIG. 33.—Junction of dolerite sill with underlying basalt lava, on slope of Cumha Cholain, north coast of Canna. Section 15 feet high. The junction here becomes irregular, and at the same time the dolerite assumes a spheroidal structure with exfoliation.

Rather less than half of the columns are six-sided, the remainder having mostly five or seven sides. The following results were found for a sill forming a double platform on the shore of Tarbert Bay. The Giant's Causeway in Ireland gave Professor O'Reilly* very similar figures, which we quote for comparison. It is clear that, in British occurrences at least, the ideal hexagonal network is rarely, if ever, realised in nature.

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* *Trans. Roy. Ir. Acad.*, vol. xxvi., p. 646 (1878).

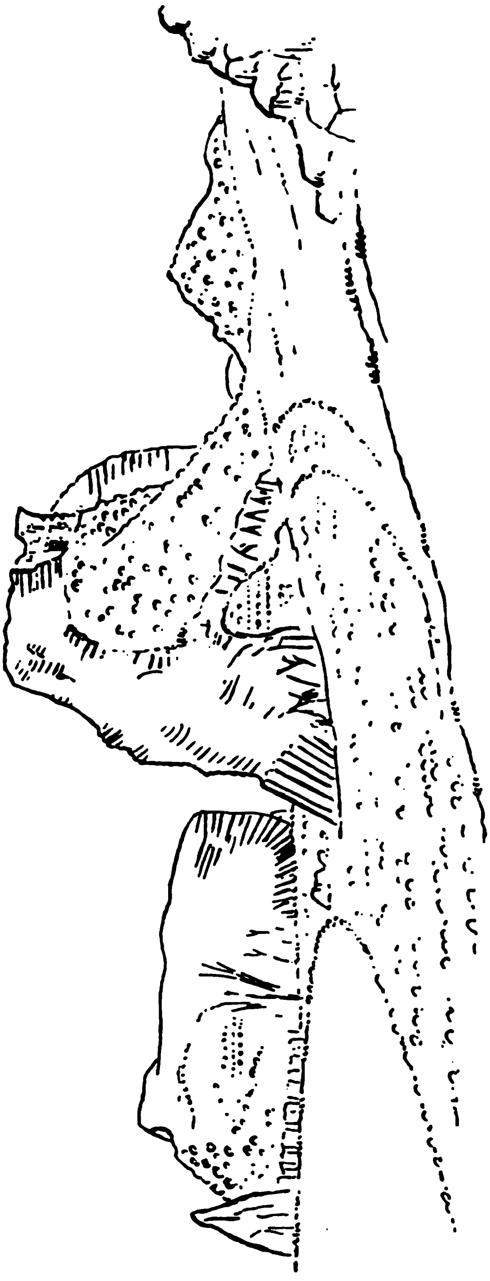

FIG. 34.—Coroghon and Alman, on the east coast of Canna; showing columnar dolerite sill behaving irregularly in contact with coarse volcanic conglomerate.

Number of sides.	*Number of columns, per cent.*	
	Canna.	Giant's Causeway.
4	2	1·98
5	36	30·73
6	44	47·7
7	16	19·63
8	2	0·66

In very many instances a sill is sharply divided into a lower and an upper portion, in which the columnar jointing is of different characters. The difference is always of the same kind, the columns in the lower part being larger and with parallel vertical arrangement, while those in the upper part are smaller and show a less regular disposition. Often the lower columns have a diameter of two, three, or four feet, while the upper ones average perhaps one foot, and are inclined, or tend to radiate. (See figs. 9, 10, 35.) The division between the two parts is sharply defined and nearly plane. It is a plane of weakness, and the upper and lower parts of the sill sometimes make two distinct escarpments. The effect is more noticeable on the coast, where this divisional plane happens to come within the zone of wave-action. In this case the upper portion of the sill may be removed, the large regular columns below being left to form a flat "causeway." (See fig. 35.) The cross-joints thus exposed are commonly plane.

In a precipitous cliff the two portions of a double sill cannot form distinct features, but the distinction between them is still very apparent. Of the three sills in the upper half of the Compass Hill cliff (figs. 9, 10), two are of this kind, the lowest being only rudely jointed and indivisible.

Double columnar sills of this kind are seen in some parts of Skye, notably on Preshal More and Preshal Beg, near Talisker*; and in the writer's description of these the upper and lower portions were considered to represent distinct intrusions. A study of the occurrences in Canna makes it probable that the supposition was incorrect as regards the particular instances cited, although the intrusion of a later sill in contact with an earlier (overlying) one has been a very frequent occurrence in Skye.

Exposed crags of dolerite on the moorland hills and plateaux often show considerable *permanent magnetisation*,† and there is in consequence a very sensible disturbance of the compass over considerable areas. This has long been observed in certain localities, but the wide distribution of effects of this kind in the Inner Hebrides does not seem to be generally known. In Rücker and Thorpe's magnetic survey of the British Isles‡ observations of

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* *Tertiary Igneous Rocks of Skye*, p. 244.

† For a specimen from Canna Dr. Hoffert found the permanent intensity of magnetisation to be ·002 in C.G.S. units. (Rücker and Thorpe, *l.c. sub.*, p. 311.) This is by no means an extreme example.

‡ *Phil. Trans. Roy. Soc.* (A), vol. 181, pp. 53–328 (1890).

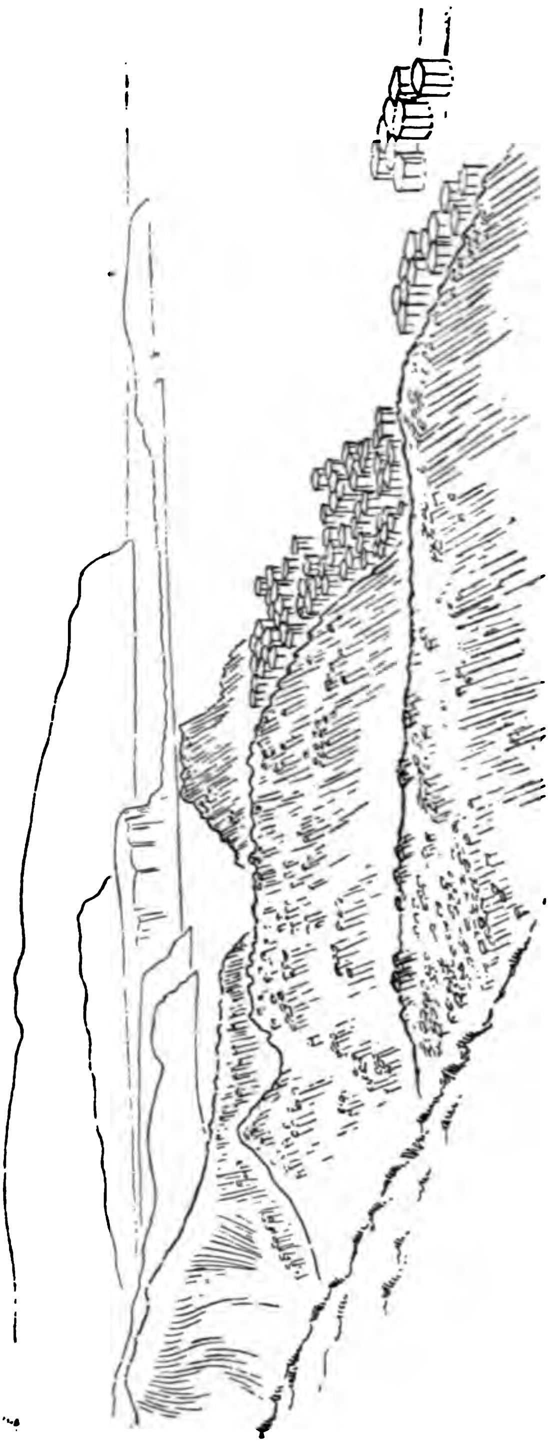

FIG. 35.—The south coast of Canna, near Geodha na Nighinn Duibhe; showing a double columnar sill. The upper portion is built of small columns with varying inclination. Where this is removed, the larger and more regular columns of the lower portion are exposed, their tops forming a regular causeway.

declination were taken at twenty-three points on the Isle of Canna. They showed deviations up to as much as 25·8°, the greatest disturbances being observed just east and west of the Compass Hill at the east end of the island. This locality, as its name imports, is famous for its magnetic disturbances; but, as Macculloch long ago remarked, it is not by any means peculiar in this respect.

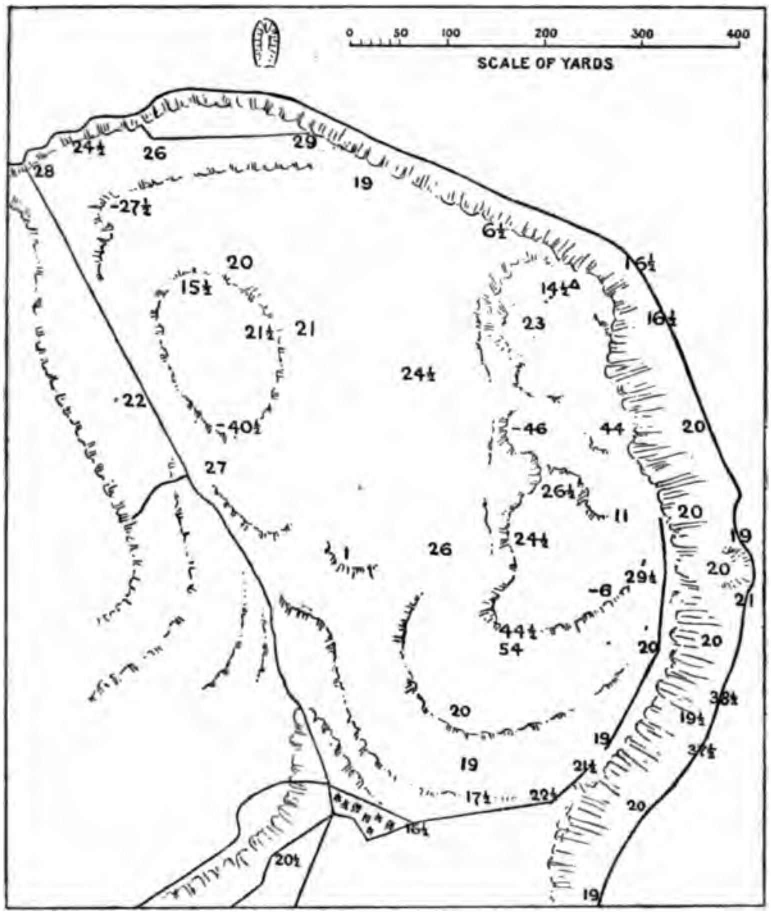

FIG. 36.—Map of Compass Hill, Canna, to show magnetic disturbances. Scale, nine inches to a mile.

The figures give the magnetic declination at different points, reckoned positive to west of north and negative to east, on 24th September 1903. The normal declination for this date would be about 20½°. The observations were taken at about five and a half feet above the ground. The summit, marked by a small triangle, is 458 feet above sea-level.

We have determined roughly the magnetic declination at fifty points on and about Compass Hill by taking bearings of distant objects with the prismatic compass, and the results are shown in fig. 36. The compass was held as high as possible above the ground to avoid the more violent local disturbances. The normal magnetic declination for the time and place may be taken as 20½°. Of the fifty observations, twenty fell within 1½° of this figure, on one side or the other, and thirty-nine fell within 10° of the normal. The greatest deviation observed was 66½°, indicating a disturbing force 2·3 times as great as that due to the horizontal intensity of the earth's magnetic field. Much greater disturbances may be verified at many localities in Skye.*

The disturbances here indicated are due to an irregular distribution of permanent magnetisation in the salient portions of the dolerite sills, which, as usual, form all the strong features. If induced magnetisation produces any effect, this is negligeable by comparison. Disturbance due to induced magnetisation should show itself by easterly deflections on the west side and westerly on the east side; but, so far as any law is discernible, the case is the reverse of this.

(ii.) PETROGRAPHY OF THE DOLERITE SILLS.

Petrographically, the rocks composing this great group of basic sills present a remarkable degree of uniformity. Excepting only the few occurrences of fine-grained rocks resembling mugearite, to be separately described below, all the sills are of *olivine-dolerite*, having as essential minerals a plagioclase felspar, augite, olivine, and magnetite. They are dark, evidently crystalline rocks, varying in coarseness or fineness of texture. The coarser varieties are met with in the most massive sills, 100 feet or more in thickness, such as that which makes a considerable spread near the pier at the south-east point of Eigg, that which occurs at or near the base of the basalts in the northern half of the same island, and that which makes the cliffs on the north-east coast of Muck. The smallest sills are of finer-grained rocks, which from their texture might be termed olivine-basalts. Apart from differences of texture and of micro-structure, but little variety is to be noted. The only distinction which may be supposed to have some significance is that depending on the absence or presence of conspicuous porphyritic felspars. Even this distinction is not a very sharp one; for there are cases in which it is difficult to decide whether some felspar crystals larger than the majority attain the rank of distinct phenocrysts, and there are other cases in which conspicuously large crystals are present, but only sparingly and sporadically.† Nevertheless, a decided porphyritic character seems to be connected with the composition of the rocks which exhibit it, these having on the whole a greater preponderance of felspar than the others; and the porphyritic sills have also a fairly defined distribution on the ground. For these reasons we shall separate for purposes of description the porphyritic dolerites from the non-porphyritic.

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* Harker, *Proc. Camb. Phil. Soc.*, vol. x., pp. 268–278.

† Compare *Tertiary Igneous Rocks of Skye*, p. 250 (1904).

The *non-porphyritic dolerites*, which were found to be the prevalent type under this group in Skye, include the great majority of the sills on Eigg and Muck. They are also well represented on Canna, especially at the lower horizons, and in places alternate with the porphyritic sills. On Sanday they are found more especially at the western end of the island. The rocks belong to a familiar type, and have a simple mineralogical constitution. A specimen from Creag a' Chairn, near Tarbert, Canna, gave the specific gravity 2·95.

Olivine is constantly present, and sometimes in crystal-grains $\frac{1}{10}$ inch in diameter, easily visible on a hand-specimen. The mineral is commonly fresh, the dolerite sills contrasting in this respect with the basalt lavas, but pseudomorphs of green serpentine are found in some of the rocks. An opaque iron-ore is fairly plentiful, usually in small crystals with the octahedral form of magnetite. This was observed also in the Skye dolerites, although analyses of those rocks yielded two or three *per cent.* of titanic acid. Presumably we have to deal here with a titano-magnetite. When the iron-ore is in irregular grains, these may be moulded on the felspar crystals. Little rods or needles of apatite are seen in many of the thin slices. The felspar is constantly idiomorphic, with elongated rectangular habit and twin-lamellation. It has in most cases the properties of labradorite. The augite has a pale-brown colour in thin slices, and usually shows a characteristic ophitic habit, more or less enveloping and enclosing the felspar crystals. Less frequently we find the "granulitic" habit, probably due, as supposed by Professor Judd, to a certain amount of differential movement in the rock during consolidation. The coming in of this character may therefore be attributed to special local conditions; and in accordance with this a given sill may show the ophitic structure in one part and the "granulitic" in another, as is the case in the thick sill in the north of Eigg, already mentioned. The two structures may even be associated in alternating narrow bands in one microscopical preparation, as in an example from the western end of Sanday [6660].*

The minerals enumerated are in general the only primary constituents of the rock. We may note, however, a special variety arising from the presence of biotite. This is seen in certain sills on the southern coast of Eigg, and notably in one near the top of the cliff of Creag nan Faoileann [11,696]. The mica is evidently a normal constituent, occurring partly in well-shaped flakes, partly in clusters surrounding the crystals of iron-ore. The rock is further exceptional in that the augite has a strong tendency to idiomorphism.

The dolerite sills occasionally contain infilled steam-cavities, giving an amygdaloidal character to the rock; but this is much less common here than in the basalt lavas, nor do the vesicles make up so large a proportion of the volume. Another point of difference may be noted. In the lavas the vesicles are usually almond-shaped, being more or less drawn out in the direction of flow. In the sills, intruded under pressure, it appears that the steam was disengaged at a somewhat later stage, after flowing movement had ceased; and the vesicles tend to be spherical, or, if larger, of somewhat irregular shapes. Sometimes, as observed at a few places in the southern part of Eigg, the vesicles are elongated vertically or at right angles to the surfaces of the sill, and may run together in that direction, producing vertical tubes with irregular constrictions and expansions. Sir Archibald Geikie* has made a like observation in Skye.

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* *Quart. Journ. Geol. Soc.*, vol. lii., p. 335 (1896).

Sills of *porphyritic olivine-dolerite* occur in great force on the Isle of Canna, where they form much of the higher ground, and are well seen on Compass Hill, Càrn a' Ghaill, Beinn Tighe, Cnoc Rugail, Sliabh Mheadhonach, &c. Good examples occur also in the eastern part of Sanday. Two conspicuously porphyritic sills are found about 700 or 800 feet above the base of the volcanic series on Eigg. Their outcrops may be traced round the base of the Sgùrr, approaching on the southern side close to the foot of the strong escarpment, and being in part cut out by the pitchstone. Sills of *porphyritic olivine-basalt* occur in the basalt outliers of Rum, both in the north-easterly spur of Fionn-Chrò and on the hill south-west of Minishal. It is noticeable that with the finer texture of the ground-mass the porphyritic felspars also become smaller.

In Skye, or at least in that part of Skye which has been surveyed in detail, conspicuously porphyritic sills comparable with these occur always in a special relationship. They are associated with the peculiar type named mugearite, the two forming parts of a composite double sill, with clear evidence that the latter rock was intruded very closely after the former.† It was conjectured that these composite basic sills constitute a distinct group of later age than the common dolerite sills of the country; but the evidence now obtained from the Small Isles negatives that supposition. Here the porphyritic olivine-dolerites form distinct sills, not associated with mugearites. They occur in much greater abundance, being on the hills of Canna the prevailing type; they occupy the place where, in their absence, we should expect to find the ordinary dolerite sills; and there is nothing in the mode of occurrence and visible relations which would lead us to separate the porphyritic from the non-porphyritic as regards the epoch of their intrusion. Further, we find in the Small Isles certain sills showing decided affinities with the mugearites of Skye, and these occur either alone or exceptionally associated in composite sills with ordinary non-porphyritic dolerites. For these reasons we shall regard both the porphyritic dolerites and the mugearite-like rocks as belonging to the principal epoch of sill-intrusions, though distinctly separable on petrographical grounds.

Dr. Pollard has made a complete analysis of a porphyritic olivine-dolerite from Canna (I), which shows that it agrees fairly in composition with the corresponding rocks of Skye (A). It has the same rather high silica-content, as compared with the non-porphyritic dolerites (B), and it shows similar figures for titanic acid, lime, soda, &c. As regards alumina and iron-oxides, on the other hand, it resembles rather the non-porphyritic type. The noticeable amount of phosphoric acid (as apatite) is perhaps significant, for a relatively high percentage of this constituent is one of the characteristics of the mugearite type.

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* *Quart. Journ. Geol. Soc.*, vol. lii., pp. 376, 377. The same author (p. 336) notes as an exceptional occurrence steeply inclined vesicles in a basalt lava.

† *Tertiary Igneous Rocks of Skye*, chap. xv.

	I.	A.	B.
SiO_2 - -	49·53	50·33	46·13
TiO_2 - -	1·76	1·81	3·60
Al_2O_3 - -	15·05	19·97	17·07
Cr_2O_3 - -	trace ?	trace	trace
V_2O_3 - -	0·01	not det.	0·03
Fe_2O_3 - -	4·49	2·81	6·61
FeO - -	9·07	6·23	8·20
NiO, CoO -	0·04	trace	...
MnO - -	0·29	0·17	0·28
MgO - -	4·25	3·24	4·38
CaO - -	8·08	8·03	7·15
BaO - -	0·05	0·06	not det.
SrO - -	strong tr.	trace	not det.
Na_2O - -	3·93	4·30	3·58
K_2O - -	1·25	1·19	1·19
Li_2O - -	trace	...	...
H_2O above 150°	1·06	0·99	1·71
H_2O at 105° C.	1·47	0·87	0·59
P_2O_5 - -	0·43	0·17	0·09
½S - -	0·07	...	...
	100·83	100·17	100·61

I. [11,730].—Porphyritic Olivine-Dolerite, sill, Ealaist, Canna: anal. W. Pollard.

A. [9250].—Porphyritic Olivine-Dolerite, sill, Druim na Criche, Skye: anal. W. Pollard, *Tertiary Igneous Rocks of Skye* (1904), p. 263.

B. [8057].—Olivine-Dolerite, sill, Broc-bheinn, Skye: anal. W. Pollard, *ibid.*, p. 248.

The general petrographical characters show little variety in different examples. The porphyritic felspars are usually about half an inch in length, or sometimes one inch. In the finer-grained rocks they do not exceed one-eighth of an inch, and in some of the sills porphyritic felspars of this small size are accompanied by a few larger ones. The crystals are of rectangular shape, with a markedly flat tabular habit, the broad faces corresponding with the brachypinacoid. They are fresh, with a glassy appearance, and the twin-lamellation is visible to the naked eye. In thin slices they are seen to contain small glass-inclusions or larger patches of ground-mass with roughly rectangular shape, sometimes also crystals of magnetite and grains of olivine. Judged by their extinction-angles, they are labradorite, though not always of the same variety: the maximum extinction-angles in sections perpendicular to the brachypinacoid range usually between 30° and 40°. Carlsbad and albite twinning are universal, but pericline lamellæ occur only inconstantly. A certain degree of zonary banding is frequent, and is especially noticeable in brachypinacoidal sections.

The general mass of the rock consists of the minerals already noted in the non-porphyritic dolerites, with the same characters but not always in the same relative amounts. Olivine and the iron-ore mineral are apparently as abundant as before, but augite is usually somewhat deficient; so that the felspar comes to have a more marked preponderance. As before, both ophitic and "granulitic" structures are met with, the former being usual; but where the augite is not very abundant it does not easily form elements large enough to enclose completely the felspar crystals.

III. OCCURRENCES OF MUGEARITE SILLS.

Lastly, we have to describe the *mugearite* sills. These have a more restricted distribution than the foregoing types, though occurrences have been found in each of the principal islands. We may note, for the sake of clearness, that the type "mugearite" was founded for certain very fine-textured sill-rocks met with in several places in Skye.* With a basic composition, they have a moderately high percentage of alkalies and rather low lime and magnesia. The dominant constituent is oligoclase, with some orthoclase; magnetite and apatite are unusually abundant; augite is only sparingly present; and olivine may occur, or, in place of it, a certain brown mica-like mineral which seems to be a new species.

In several localities in the Small Isles we find sill-rocks which differ from the ordinary dolerites in their dark compact aspect, their mode of fracture, the tendency of their non-porphyritic specimens, and other peculiarities, and which at once recall the mugearites of Skye. A microscopical examination brings out many points of resemblance, and, although there is some divergence, both in mineralogical and in chemical composition, from the original type, we shall place these rocks at least provisionally with the mugearites. We give first a notice of the several occurrences and then a summary account of the petrographical characters.

It was Sir Archibald Geikie† who first noted a rock of this group as something to be definitely separated from the more ordinary types of basic rocks in the region. This was in the Isle of Eigg. On the small sketch-map accompanying the memoir cited, the rock is shown as making a considerable spread in the neighbourhood of Laig and again near Kildonan, and it is stated that it [illegible] [illegible] the northern part of the [illegible] [illegible] [illegible] near the

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* Tertiary Igneous Rocks of Skye, pp. 263–268; 1904.

† Quart. Journ. Geol. Soc., vol. xxvii, pp. [illegible]; 1871.

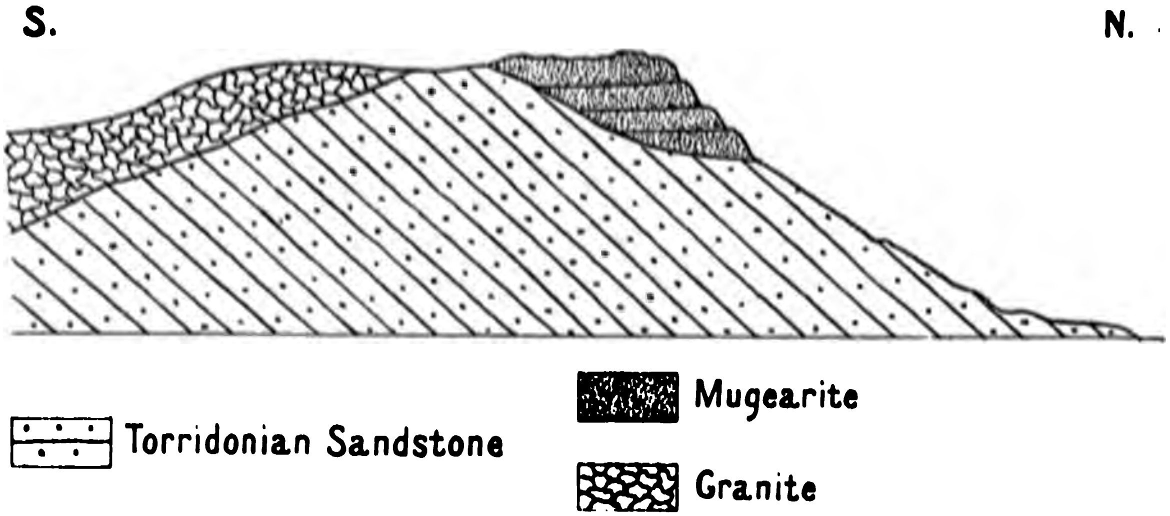

FIG. 37.—Section through Creag nan Stairdean (Bloodstone Hill), Rum. Scale, six inches to a mile.

The surface of junction of the mugearite with the sandstone is presumed to represent the pre-Tertiary land-surface, on which the basaltic lavas were poured out. The subsequent invasion of the latter by intrusive sills of mugearite has left only meagre relics of basalt intervening in places between the sills.

base of the volcanic series. Mr. Barrow, in mapping out its course, found evidence that it is intrusive in the basalt lavas. He traced the mugearite for some distance along the coast on the south side of Laig Bay. At Kildonan he found it to consist of two distinct sheets, in contact with one another but making separate escarpments. Southward from here the lower sheet cannot be distinguished far beyond the road, but the upper can be followed until it dies out some 500 yards south of the Manse. Sir Archibald Geikie, who examined the rock microscopically, terms it a porphyrite, and describes it as "a highly felspathic basalt-rock in which the ferruginous silicates are poorly developed."

A sill of mugearite occurs at the base of the basalt lavas at Camas Mòr, in *Muck*, and is exposed in the lower part of the cliff at the head of the bay.

In the north-western part of *Rum* rocks of the mugearite group attain a development not found in the other islands. They make the two hills Creag nan Stairdean (or Bloodstone Hill) and Fionn-Chrò, and are found in the form of a succession of nearly horizontal sheets with an aggregate thickness of about 460 feet in the former hill and 560 feet in the latter. The two are doubtless outlying relics of one continuous succession of sheets, the original thickness of which may have been still greater. In Creag nan Stairdean (fig. 37) the regular base of the sequence rests upon the truncated edges of the sharply inclined Torridonian sandstone. In Fionn-Chrò (fig. 29) about 400 feet of basaltic lavas occur below the mugearite, which comes immediately above the river-gravels and tuffs already mentioned (p. 50). In both occurrences the mugearite impinges upon the northern border of the main granite area. No further indication of the mode of occurrence of the rocks is to be obtained, for the Creag nan Stairdean area is isolated, and that of Fionn Chrò is bounded to north and east by faults.

The evidence regarding the relations of the mugearite of Rum is thus ambiguous, and is not sufficient in itself to decide whether we have to deal here with a succession of surface flows or with a group of sills intruded in the lower part of the basalt group. The latter alternative is, however, the more probable. No rocks resembling these are known among undoubted Tertiary lavas in Britain, and it is difficult to suppose that the 300 feet of basalt seen at the western end of Fionn-Chrò have completely thinned out before reaching Creag nan Stairdean, about half a mile farther west. If the mugearites be intrusive sills, there is no difficulty in supposing that they cut obliquely down to the base of the volcanic series between the one hill and the other. The regular escarpments formed by the individual sheets, and the fact that the principal sheet on Fionn-Chrò has a thickness of fully 250 feet, are more easily reconciled with the behaviour of sills than of lava-flows. The resemblance of the rocks themselves to the undoubtedly intrusive mugearites of Skye, Canna, and Eigg is a further argument of weight. An apparent objection is the fact that these Rum mugearites come into direct juxtaposition with the granite. In no other case examined in the Tertiary districts of the Inner

Hebrides do sill-formed intrusions of the hypabyssal phase approach so closely to the plutonic masses. The exception seems, however, to find an explanation in the comparatively slight metamorphism which the granite has produced in the basalts in this neighbourhood. The bedding of the lavas has not been, as usual, obliterated as a direction of weakness; and it is noticeable that on Fionn-Chrò the undoubtedly intrusive dolerite sills in the basalt group themselves approach close to the granite boundary.

The most beautiful rock of this set is found on Eilean a' Bhaìrd, a small island in *Canna Harbour*. It makes the lower member of a double sill, the upper part of which is an ordinary olivine-dolerite*; and, although the demarcation between them is fairly sharp, the two rocks have doubtless an intimate relationship. It will be recalled that in the Skye occurrences the mugearite always appears as the lower member of a similar double sill, but the upper member there is a porphyritic olivine-dolerite which has more evident affinities with the mugearite itself. (See Analysis A, p. 125.) The double sill on Eilean a' Bhaìrd is soon lost below sea-level in consequence of the westerly dip (fig. 38). Another

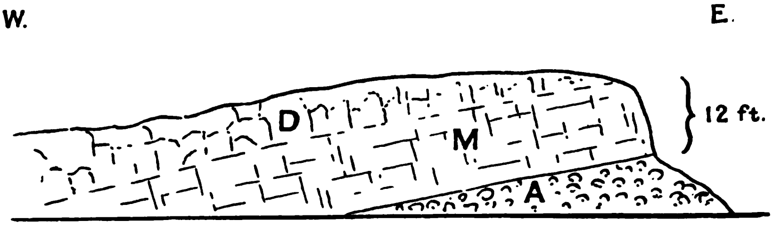

FIG. 38.—Section of composite double sill on Eilean a' Bhaìrd, Canna Harbour. D = dolerite; M = mugearite (12 feet); A = volcanic agglomerate.

mugearite, or possibly another appearance of the same, is seen at the base of the cliff below Compass Hill, at the north-east point of Canna. Here again the rock is surmounted by ordinary dolerite, the two forming what is in effect one composite sill.

The mode of occurrence of the Canna mugearites strengthens the evidence for assigning these rocks to the same epoch as the ordinary dolerite sills. From the underlying position of the mugearite we may infer that it was intruded slightly later than the dolerite, and it is worthy of note in this connection that all the mugearites of the Small Isles occur in the lowest part of the volcanic series. We may remark in passing that in Rum and Eigg the mugearites are displaced by the ordinary plateau-faults of the region, a fact which would forbid us to assign these rocks to a late epoch.

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*This upper member has, however, some characters which assimilate it in composition to the porphyritic dolerites, and more remotely to the mugearites. Magnetite is rather plentiful, and the felspar gives low extinction-angles [11,708].

(iv.) PETROGRAPHY OF THE MUGEARITES.

The rocks of the several occurrences may be described collectively, and we shall remark first their chemical composition. Dr. Pollard has made *complete analyses* of specimens from Canna and Rum, and the results are reproduced in Columns II. and III. These rocks were selected as being in some measure peculiar: the mugearites of Eigg and Muck would doubtless give figures agreeing much more closely with those for the type-rock from Skye (Column C). It will be seen that the two rocks analysed have the relatively high silica-percentage (50) which belongs to the mugearites and the porphyritic olivine-dolerites, as contrasted with the lower percentage (45 or 46) in the common non-porphyritic sills. The low content of alumina is significant in the same sense. On the other hand, the lime is higher and the soda lower than in the Skye mugearite, the figures here agreeing more nearly with those for the common type of sills (B). As regards

	II.	III.	B.	C.
SiO_2 - - -	49·92	50·70	46·13	49·24
TiO_2 - -	2·04	1·89	3·60	1·84
Al_2O_3 - -	12·83	14·60	17·07	15·84
Cr_2O_3 - -	trace	not det.	trace	trace
V_2O_3 -	0·04	not det.	0·03	not det.
Fe_2O_3 - -	6·96	5·23	6·61	6·09
FeO - - -	6·21	7·68	8·20	7·18
NiO, CoO - ·	0·03	tr. Ni	...	trace
MnO - -	0·52	0·42	0·28	0·29
MgO - -	3·78	4·15	4·38	3·02
CaO - - -	7·25	7·20	7·15	5·26
BaO - - -	0·09	0·08	not det.	0·09
SrO - - -	trace	trace	not det.	trace
Na_2O - -	3·72	3·71	3·58	5·21
K_2O - - -	1·73	1·33	1·19	2·10
Li_2O - -	trace	trace ?	...	...
H_2O above 105° -	1·05	1·15	1·71	1·61
H_2O at 105° C. -	3·58	2·08	0·59	1·08
P_2O_5 - -	0·45	0·49	0·09	1·47
F - - -	...	...	...	0·18
S - - -	trace ?	...	...	0·03
	100·20	100·71	100·61	100·46

II. [11,731].—Sill (below dolerite), Eilean a' Bhàird, Canna Harbour: anal. W. Pollard.

III. [11,732].—Sill, on pass at south base of Fionn-Chrò, Rum: anal. E. G. Radley.

B. [8057].—Olivine-Dolerite, sill, Broc-bheinn, Skye: anal. W. Pollard, *Tertiary Igneous Rocks of Skye* (1904), p. 248.

C. [8732].—Mugearite, sill (below porphyritic olivine-dolerite), Druim na Crìche, Skye: anal. W. Pollard, *ibid.*, p. 263.

magnesia, potash, and phosphoric acid the Analyses II. and III. are intermediate between B and C. Chemically, then, these rocks from Canna and Rum stand midway between typical mugearites and dolerites; but the petrographical characters assimilate them decidedly to the latter. The examples from Eigg and Muck may be considered typical mugearites.

The rocks are close-grained, and, when fresh, have a black or very dark-grey colour. Determinations of specific gravity gave—

Cliff north of Kildonan, Eigg, - - -	2·662
Eilean a' Bhaìrd, Canna, - - - -	2·75
East face of Fionn-Chrò, Rum, - - -	2·82

A few scattered felspars, of fresh aspect but small dimensions, are the only constituents visible to the naked eye. Amygdaloidal structure is not infrequent, and in some cases the cavities are of considerable size: the substances enclosed differ, as will be noted below, from those in the basalt lavas and in the occasionally amygdaloidal dolerite sills. In Eigg, where the mugearite is usually altered to a light-grey colour, the cavities are generally empty. The very thick sheet which forms the basal part of the succession in Fionn-Chrò, and makes a strong escarpment, has throughout its extent a curious brecciated structure, which makes it impossible to obtain a good specimen of the rock; and something of the same character is seen in other sheets, both here and on Creag nan Stairdean. The Eilean a' Bhaìrd sill has a pronounced platy fracture, agreeing with the direction of flow and depending chiefly upon the much-flattened amygdaloidal cavities. The weathered parts of the Eigg mugearite also break almost like a slate, resembling in this respect the similar rocks in Skye.

In most of the sills small crystals of felspar, rather sparsely distributed, give a micro-porphyritic character to the rock. They are from ·01 to ·03 inch in length, or exceptionally to one-eighth of an inch. In different examples they range from labradorite to oligoclase, and a few untwinned crystals may be of potash-felspar. Augite and magnetite are less frequent as porphyritic elements, but sometimes occur associated with the felspar to form "glomero-porphyritic" aggregates. The Eigg and Muck mugearites contain no porphyritic elements, except occasional little crystals of magnetite, ·02 inch in diameter.

The general mass of the rock always consists largely of slender felspar microlites. In the very fine-textured varieties these are about ·002 inch in length; when rather larger they often show twinning. In all cases these microlites give sensibly straight extinction in relation to their length, and there can be no doubt that they are chiefly of oligoclase. Probably orthoclase is also represented in smaller amount, for the potash shown in the analyses is too much to be accommodated in a plagioclase felspar. The mineral next in importance to felspar is magnetite, which is always abundant in small octahedra and granules. We may infer from the chemical analyses that it is titaniferous. Augite is less abundant, though in larger amount than is usual in the Skye mugearites. It is usually in very minute granules. In the sill at the summit of Fionn-Chrò the augite is more plentiful, and tends to idiomorphic shapes. This rock also contains olivine, which is not usually distinguishable in the mugearites of the Small Isles, though other specimens from Rum have deep red-brown pseudomorphs which have probably originated from this mineral. Apatite is doubtless of general occurrence, though the slender needles are often obscured by the dark alteration-products of the rock. Sometimes they are very numerous (Compass Hill). The mugearites of Eigg and Muck contain abundant little brown pleochroic flakes, which are usually biotite, but in one or two slices appear to agree in their properties with the unknown mineral already recorded in the Skye rocks (Pl. VII., fig. 2, *A*).

The specimens from Eigg, Muck, and Canna show no clear trace of any glassy residue, though it is possible that it is sometimes concealed by ferruginous alteration-products. The Rum mugearites represent a somewhat different variety. Here the felspars of the ground-mass are often not so minute as in the rocks from the other isles, being frequently about ·01 inch in length, and the interspaces between these and the other crystalline elements are occupied by an abundant brown glass. In the rock from Eilean a' Bhaird chlorophæite sometimes occurs in the same interstitial fashion, and it is possible that it replaces in part a glassy base, not otherwise discernible. This mineral shows a strong yellowish-brown colour in thin slices. Usually it appears to have little or no action on polarised light; but this is probably a consequence of its micro-structure, for in some small spherical vesicles which it occupies as a radiating fibrous aggregate it is seen to be birefringent, with straight extinction, giving a distinct "black cross" effect.

The mugearites are often amygdaloidal, the cavities being sometimes small and round but more frequently large and elongated. They then take the form either of narrow spindles or of much-flattened ellipsoids, and may have a length of two or three inches. These cavities are occupied either by chalcedony or by chlorophæite, the two minerals usually occurring separately, though they may be found in adjacent cavities. The empty ellipsoidal cavities in the weathered mugearite of Eigg are probably due to the removal of chlorophæite which once filled them.

The *chlorophæite* is of some interest, since the mineral was first described and named by Macculloch* from material obtained at Sgùrr Mòr (or Creag nan Stairdean), in Rum. No closer examination was made of the mineral for sixty years, and meanwhile the name had been applied by mineralogists to several quite different substances from other localities. Professor Heddle published in 1879 a description of the original chlorophæite with a chemical analysis, which is here quoted in Column IV.; and he attached it to the "saponites" as distinguished from the chlorites. Its non-aluminous nature, however, would seem to separate it equally from both groups, and it has nothing of the flaky habit or cleavage. In a thin slice it gives a strong yellowish-brown colour, and has no sensible birefringence in the larger patches, but this seems to be explained by a very fine granular structure.

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* *Description of the Western Islands of Scotland*, vol. i., pp. 504-506 (1819). On the Ordinance map, which we follow, the bold hill is named Creag nan Stairdean, while the name Sgùrr Mòr is attached to the ridge which runs south-west, presenting a steep face to the sea. In Rum the former is generally known as Bloodstone Hill.

	IV.	V.	VI.
SiO_2 - -	36·0	17·746	57·725
Al_2O_3 - -	...	0·535	0·33
Fe_2O_3 - -	22·8	49·672	17·047
FeO - -	2·462	2·147	3·729
MnO - -	0·5	1·196	0·076
MgO - -	9·5	3·988	3·843
CaO - -	2·52	3·07	0·602
Na_2O - -	tr.	...	0·423
K_2O - -		...	5·551
H_2O above 100° -	7·236	11·361	4·788
H_2O at 100° C. -	19·227	10·454	5·99
	100·254	100·172	100·204
Sp. gravity - -	(2·02)	...	2·574

IV.—Chlorophæite, Creag nan Stairdean ("Scuir Mohr" of Heddle), Rum: anal. M. F. Heddle, *Trans. Roy. Soc. Edin.*, vol. xxix., p. 87 (1879). (Specific gravity from Macculloch.)

V.—Decomposition-product of chlorophæite, same locality: anal. M. F. Heddle, *ibid.*, p. 88.

VI.—Celadonite, same locality: anal. M. F. Heddle, *ibid.*, p. 103.

On Creag nan Stairdean and also on the southern face of Fionn-Chrò the chlorophæite occurs in small round amygdaloidal cavities. At Eilean a' Bhàird in Canna Harbour much finer specimens may be obtained, filling flat cavities an inch to three inches long. Heddle[*] states also that specimens several inches long are found near a cave on the south-west side of Canna, which suggests a possible occurrence of mugearite not detected in the course of our survey, though it is possible that the chlorophæite occurs also in the amygdaloidal basalts.

The most characteristic property of the mineral is the rapid change which it undergoes on exposure to the air. From a translucent green it turns to a deep brown or nearly black, having still a vitreous or sub-vitreous lustre, and closely resembling asphalte. This seems to be a physical rather than a chemical change; but the mineral also decomposes, yielding a chocolate-brown powdery substance which was also analysed by Heddle (Column V.).

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[*] *Mineralogy of Scotland*, vol. ii., p. 145 (1901).

Besides the fusiform and almond-shaped forms, chalcedony, sometimes accompanied by crystals of quartz, occupies geodes of larger size and in places forms discontinuous bands in the mugearite. The silica is usually stained to tints of grey, light brown, lavender, and especially green, ranging from pale emerald to deep jade-colour; and in this way arise many varieties of onyx, agate, prase, and heliotrope. These are found on the upper part of Creag nan Stairdean and to a less extent on Fionn-Chrò. The former is the locality of the "*bloodstone*," which was at one time well known, a rough road having been made across the island for the purpose of working it. The old workings were in the northern face of the hill, not far below the summit, the principal occurrence being a solid band about nine inches thick. This is now covered, but pieces of the bloodstone may be obtained here and from the screes below. It is of a deep green colour, with spots of blood-red. A thin slice shows a field mottled with light-green and colourless portions, sharply separated. The colourless are chalcedony with a finely-tufted quasi-spherulitic structure. The light-green substance has the form of clusters of little spherules, partly coalescing; but no radiate structure is apparent, and the substance is sensibly isotropic. This green colouring-matter of the bloodstone seems to be the same which occasionally occupies some of the flat amygdaloidal cavities in the mugearite, and it is identified by Heddle as celadonite. His analysis of it is quoted in Column VI. In spite of its non-aluminous composition, he places this substance also in his saponite group. The red spots in the bloodstone are perhaps connected with the oxidation of pyrites, minute crystals of which, in a partly altered state, are visible in a thin slice. Many specimens again contain little brown patches which are globular aggregates of chalybite, tending to become oxidised.

CHAPTER XI.

MINOR ACID INTRUSIONS (RUM AND EIGG).

(i.) RUM.

Hypabyssal intrusions of acid composition (quartz-felsites, granophyres, &c.) occur in Rum and Eigg, but not in the other islands included in the present memoir. They appear to fall into their due place in the general sequence, as already made out in Skye. A group of acid rocks is there recognised as representing an early episode in the hypabyssal or post-plutonic phase of activity,[*] and to the same group we may refer the rocks to be described in the present chapter. They are younger than the plutonic intrusions, younger also than the great group of dolerite sills. On the other hand, they are affected by tbe faulting of the region, and are freely intersected by the basic dykes. From this group we must separate another, comprising subacid rocks, which belong to a later epoch, being younger than the faults and younger also than the basic dykes. These latter rocks, which are normally pitchstones, will be noticed in a later chapter.

The most important post-plutonic intrusions in the Isle of *Rum* are of an acid rock, which may be termed a *porphyritic quartz-felsite.* It has been intruded with an irregular sheet-like habit, always among the Torridonian crush-breccias, and so usually at some distance above the principal surface of overthrusting. The largest area, nearly 1¼ mile long, occupies the upper parts of the southern mountains, Ashval and Sgùrr nan Gillean (fig. 39). Its thickness must be quite 500 feet, and it appears to be a single intrusive body. Its lower surface is in places rather irregular, and it sends out two tongue-like offshoots; one on the east side, in Stony Corrie, and the other at the northern end, cutting into the. eucrite above Bealach an Fhuirain. The thickness seen is perhaps not much less than the original thickness of the sheet, for one or two small patches of crush-breccia occur on Sgùrr nan Gillean, which seem to lie on the quartz-felsite. There is a general inclination towards the east. On the west side of Ashval, at the head of Fiadh-innis, a thin sheet of the felsite occurs in the disturbed Torridonian rocks, and between these and the gneiss: this is probably another offshoot connected with the main body. A mile east of Ashval a rather thick sheet forms the upper part

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[*] *Tertiary Igneous Rocks of Skye*, chap. xvi. (1904).

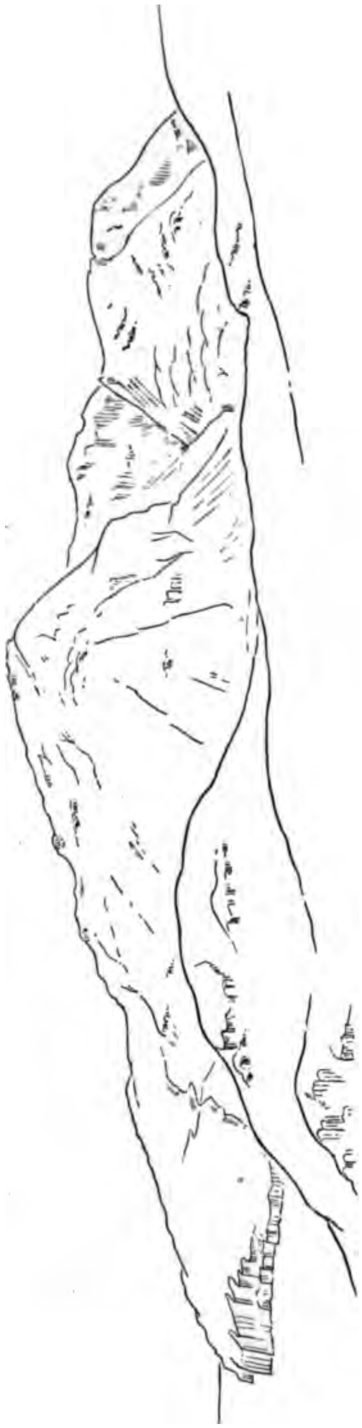

FIG. 39.—Outlines of Sgùrr nan Gillean and Ashval, seen from the east, from near Dibidil. The summit ridge is made by a thick sheet of porphyritic quartz-felsite, which also runs down into Stony Corrie, a tributary of Glen Dibidil. The slopes are mostly of overthrust and crushed Torridonian strata.

of Beinn nan Stac, surmounted, however, by a small cap of crush breccia.* Thin sheets of basalt are found at its upper and lower surfaces. It may represent the continuation of the Ashyal sheet. It is intruded almost at the actual surface of overthrust, and abuts also upon the eucrite on the north. On Beinn nan Stac, as we have seen, the surface of overthrust plunges sharply down to the south-east, and here, at the foot of the hill, another sheet of the felsite, of no great thickness, is associated with the crush-breccia and with a small lenticular intrusion of gneiss. It seems to have a vertical position, like a dyke.

Farther north the porphyritic quartz-felsite appears again forming Cnapan Breaca and Meall Breac, the two hills on either side of Coire Dubh. Both intrusions are in the crush-breccia, but impinge also against the overlying eucrite. The Cnapan Breaca mass is of lenticular form, half a mile long, and probably about 400 feet thick at the maximum. It dips S.S.W., in accordance with the general structure at this locality. Along part of its southerly or upper border, where it is in contact with the eucrite, it is crowded with *débris* of that rock, the xenolithic belt having a width of as much as 50 yards. A similar phenomenon is more strikingly exhibited by the Meall Breac intrusion, which is an irregular lenticular mass two-thirds of a mile in length and about 500 feet in thickness. (See section, fig. 4.) It touches the main body of eucrite only at the southerly extremity, and it is the breaking up of small outlying masses of that rock that has furnished the *débris* abundantly enclosed in certain parts of the felsite. At two or three places on its eastern side the felsite intrusion is bordered by narrow strips of eucrite, and in the northern part several masses of eucrite occur in the interior of the felsite of dimensions up to 100 yards and more. They might appear, on a hasty view, to break through the acid rock, but they are in fact enveloped by it. Another enclosed patch, 100 yards long, consists of Torridon sandstone and gneiss. In the same neighbourhood the felsite is often crowded with xenoliths of eucrite and sandstone. Other places rich in xenoliths, of eucrite only, occur near the western border of the felsite area. (See map, fig. 40.)

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* See Fig. 5, on p. 14. The porphyritic quartz-felsite appears as if cut *off by the* underlying eucrite ; but it is in reality the younger intrusion, and *has been abruptly* arrested by the massive plutonic rock.

The three or more distinct sheets or laccolites of porphyritic quartz-felsite have the same well-marked petrographical characters, and clearly belong to one natural group. The epoch of intrusion can be fixed with some closeness. The inclusions of eucrite and gneiss prove the felsite to be younger than all the plutonic rocks; and it is further noteworthy that the rock is not affected by the disturbances which have produced brecciation in the gneiss on the south side of Sgùrr nan Gillean. On the other hand, the Meall Breac felsite is dislocated by a fault, which doubtless belongs to the "plateau" system. The rock must therefore be assigned to the principal group of minor acid intrusions; and it is in accordance with this that it is intersected by all the basic dykes and sheets which encounter it.

A constant feature of the porphyritic quartz-felsite is a strongly marked flow-structure. The direction of this varies considerably, not usually conforming with the general lie of the intrusive sheet. On the western flanks of Ashval and Sgûrr nan Gillean the dip is to south-east or south at angles of 30° to 60°. On the east side the dips are often higher or sensibly vertical, especially where the sheet itself becomes irregular and sends out tongues. The vertical flow-structure has not a constant strike, but near the edge of the mass it is parallel with the boundary. In the intrusions of Cnapan Breaca and Meall Breac the direction of flow, though variable, is never very steep, and shows a rough general correspondence with the inclination of the laccolitic masses themselves.

A chemical analysis by Dr. Pollard, here reproduced, shows that the porphyritic quartz-felsite is of acid, but not highly acid, composition, and is richer in soda than in potash. The equivalent mineralogical composition may be calculated approximately as follows:—

Quartz,	31
Orthoclase,	18
Albite (Ab_9An_1),	40½
Augite (diopside),	4½
Iron-ore and apatite,	6
	100

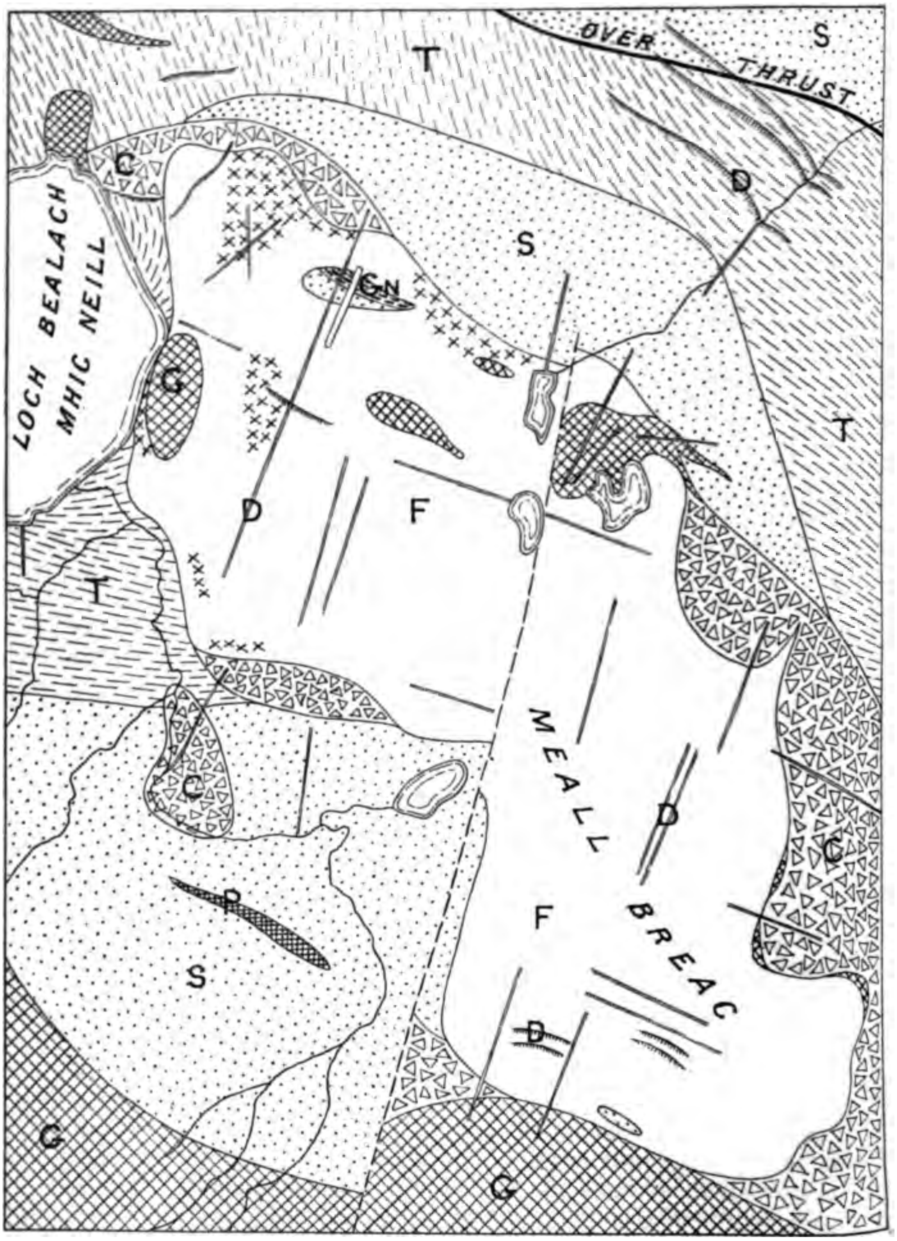

FIG. 40.—Geological Sketch-map of the neighbourhood of Meall Breac, Rum. Scale, nine inches to a mile.

D, basic dykes and sheets.
F, porphyritic quartz-felsite.
× ×, xenoliths of eucrite, &c., in the felsite.
GN, gneiss lenticle.
G, eucrite and gabbro.

P, peridotite, a small laccolite.
C, crush-breccia }
S, sandstone } Torridonian.
T, shale }

There appear to be no analyses of rocks of this group from other parts of the British Tertiary region; but we quote in Column A the analysis of an acid rock of somewhat earlier age, from one of the composite sills of Skye.

	I.	A.
SiO_2 - - -	71·53	71·98
TiO_2 - - -	0·64	0·37
Al_2O_3 - -	12·00	13·13
Fe_2O_3 - -	2·90	1·33
FeO - - -	2·02	1·64
NiO, CoO - -	0·02	not det.
MnO - -	0·36	0·14
MgO - - -	0·62	0·56
CaO - - -	2·33	1·15
BaO - - -	0·08	trace
SrO - - -	trace?	...
Na_2O - -	4·27	2·98
K_2O - - -	3·06	4·93
Li_2O - -	trace?	...
H_2O above 105° -	0·36	1·38
H_2O at 105° C. -	0·13	0·39
P_2O_5 - -	0·17	0·19
Cl - - -	...	0·01
	100·49	100·18

I. [11,734].—Porphyritic Quartz-Felsite, west slope of Ashval, Rum: anal. W. Pollard.

A. [7064].—Hornblende-Granophyre, Beinn a' Chairn, Skye: anal. W. Pollard, *Tertiary Igneous Rocks of Skye*, p. 216 (1904).

In hand-specimens the rock shows abundant crystals of glassy-looking felspar, $\frac{1}{10}$ to $\frac{1}{5}$ inch long, and occasional small grains of quartz, set in a dark-grey ground. This latter is composed of lighter and darker streaks following the direction of flow.

Thin slices show that the rock contains crystals of quartz, sanidine, oligoclase, augite, and magnetite. The felspars are often zoned, and both these and the quartz contain abundant glass-inclusions, and are often much corroded. The augite, when fresh, is of a pale, greenish variety, but it is often densely charged with magnetite dust. There are sometimes other crystals of augite, more or less transformed to hornblende, which are perhaps xenocrysts derived from the eucrite, and a rare crystal of enstatite is probably from the same source. The primary magnetite is in small octahedra, and there are sometimes a few crystals of apatite.

The ground-mass which encloses all these minerals varies in structure in different streaks and lenticles, which follow the lines of fluxion and wind round the larger crystals. Much of it is very finely crystalline or cryptocrystalline, with all the appearance of a devitrified glass, and there are parts which are still glassy. This ground-mass is often much darkened by finely disseminated magnetite dust.* Contrasted with this devitrified or still vitreous mass, there are clearer streaks with an evidently crystalline structure, showing a strong tendency to a micrographic arrangement, and sometimes becoming a regular and delicate micropegmatite.

We have remarked on the frequency of *extraneous fragments* in this rock. Even specimens from places where no xenoliths were noticed may be found to contain an occasional minute fragment of grit, doubtless derived from the crush-breccias, and a thin slice sometimes shows derived quartz-grains which come from the breaking up of the grit. Where the rock is rich in xenoliths of grit, the dark-grey matrix sometimes assumes a finely crystalline aspect from being crowded with foreign quartz-grains [10,481]. There is no very evident chemical reaction between these latter and the enveloping magma. In the same way granite xenoliths may be seen breaking up into their component crystals. In the *débris* of eucrite and gabbro mechanical disaggregation has been accompanied by chemical reaction between the basic minerals and the acid magma. Again, half-dissolved inclusions of basalt have given rise to a considerable development of brown mica at their contact with the enveloping matrix, and the brown mica which exceptionally takes the place of augite in the xenolith-bearing quartz-felsite is probably to be ascribed to reactions of this kind [10,503].

Acid dykes are very rare in Rum. One occurs in the extreme south of the island, at Rudha nam Meirlach. It traverses the Torridonian shales in a direction N. by W.-S. by E., agreeing in its bearing with the neighbouring basic dykes. The rock is a spherulitic quartz-felsite, containing crystals of quartz and orthoclase and dull white spherulitic spots in a compact grey matrix. In a thin slice it shows a tufted arrangement of fibres, the tufts interlocking with one another, or in places an axiolitic structure following lines of flow [11,692].

(ii.) EIGG.

In *Eigg* there are two distinct occurrences which fall into the group under consideration, and these will be noticed severally. Both may be described as *spherulitic quartz-porphyries*, though their actual characters are somewhat variable.

One locality is in the extreme north of the island, where a sheet-like mass nearly 100 feet thick occurs in the cliff and extends to form the reef named Eilean Thailm. This rock has a beautiful columnar structure, a feature much less common in acid than in basic sheets in this region. There are quartz-grains, which in a thin slice are seen to have corroded outlines. The ground-mass is cryptographic to micrographic in structure, with tufted arrangement rather than perfect spherulites.

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* A specimen from the Cnapan Breaca mass was described by Sir A. Geikie, *Trans. Roy. Soc. Edin.*, vol. xxxv., p. 134 (1888).

The second mass is that of Sròn Laimhrige, east of Laig farm and beside the road to Cleadale village. It seems to have a general sheet-like habit, but with some irregularity of behaviour. The rock contains corroded grains of quartz in a ground-mass of variable characters. The main part of the intrusive body has a "granophyric" tendency, with minute and delicate intergrowths of felspar and quartz. Near the margin, and especially in a narrow dyke-like offshoot which crosses the high-road, the micro-structure varies. In one variety the ground-mass shows very numerous little rectangular crystals of orthoclase set in a minutely granular or almost cryptocrystalline matrix. In another slice the little felspar crystals have hollow and skeletal forms, and the very finely textured matrix is suggestive of a devitrified glass [10,769]. Finally, the terminal part of the tongue or dyke becomes a pitchstone.* This is a vitreous-looking rock of olive-brown colour, with specific gravity 2·51. It has the usual corroded quartz-grains, with an occasional pseudomorph after some ferro-magnesian silicate, and the microscope shows slender skeleton crystals of felspar, as in the last specimen; but the general matrix, making the bulk of the rock, is a clear glass, enclosing minute crystallites (apparently felspar rods) with stellate grouping [10,770]. It will be noticed that the glassy character comes in here only as a special modification of the normal rock, and the pitchstone which thus arises differs in several respects from the pitchstones of the later group, to be described in their place.

The occurrence of acid hypabyssal rocks on the Isle of Eigg is of interest in connection with certain theoretical considerations which may be briefly mentioned in this place. In the Inner Hebrides in general those groups among the Tertiary igneous rocks which have a regional distribution are of basic composition. Acid rocks on the one hand and ultrabasic on the other seem to be limited to certain local centres, where the processes of magmatic differentiation had fuller play; and these special centres of differentiation coincide with the places where activity was exclusively concentrated during the plutonic phase. We are thus led to conjecture that Eigg may be one of these centres, although erosion has not actually brought to light any plutonic intrusions in this island.

The minor intrusions of acid rocks on Eigg are not the only fact to suggest this speculation. One remarkable feature of such plutonic centres as those of central Skye and southern Rum is that in these districts, and not elsewhere, the volcanic agglomerates (and the river-conglomerates derived from them) contain *débris* of granite and gabbro. These fragments of plutonic rocks closely resemble the corresponding rocks which were subsequently intruded in the immediate neighbourhood, their areal distribution being in remarkably close correspondence.† We have thus to recognise at these centres an earlier suite of plutonic rocks, which have nowhere been brought to light in mass, but which foreshadowed the known plutonic intrusions of a later phase in the development of igneous activity. Now we have already remarked (p. 52) that fragments of such plutonic rocks are found in the volcanic agglomerate of Bidein Boidheach, where the Sgùrr of Eigg terminates at the coast. Here therefore we have another fact suggesting the possible existence of a concealed plutonic centre beneath the Isle of Eigg.

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* This pitchstone was first noted by Hay Cunningham, *Mem. Wern. Soc.*, vol. viii., pp. 159, 160 (1839).

† *Tertiary Igneous Rocks of Skye*, p. 24 (1904).

CHAPTER XII.

BASIC DYKES.

(i.) GEOLOGICAL RELATIONS OF THE DYKES.

One of the most striking features of Tertiary igneous activity in the British area is the profusion of dykes of basic composition, which intersect the pre-Tertiary strata, the basaltic lavas, and most of the other igneous rocks. These dykes are well represented in most parts of the Small Isles. We shall first notice their occurrence in the several islands, and then make some remarks on the various types of rocks met with, though without attempting a comprehensive description. It is to be observed that, in places where the dykes are very numerous, only a small fraction of them are shown upon the map.

Beginning with the *Isle of Rum*, we find that the basic dykes are very numerous, about 700 having been recorded in the course of the survey, or an average of more than 16 to each square mile. They are, however, by no means evenly distributed over the area. This is shown on the sketch-map (Pl. III.), on which most of them are indicated; though, in places where they are closely set and parallel, one dyke is sometimes marked in place of two or three. The main facts of distribution are clearly related to general principles, which are traceable by like effects in Skye and elsewhere.

Firstly, the influence of the country-rock is very evident, being most marked on a comparison between the Torridonian and the granitic areas. The Torridon sandstone is in most places intersected by numerous dykes. It is not in itself a rock affected by dykes where any alternative is open to them; but in Rum, where this formation immediately underlies the whole island, the question of an alternative does not enter. The tract of plutonic rocks contains abundant dykes in the eastern half, but comparatively few in the western. In particular, the principal granite area, in the west of the island, is in most parts free from dykes, though a noteworthy exception occurs along the strip of coast between A' Bhrìdeanach and Harris. The paucity of dykes on this part of the map is not due to any difficulty in detecting them; for those which occur are very conspicuous, and the rocks are in general well exposed. It is due to some peculiarity in the nature of the country-rock. In Skye* the sparseness of dykes in the granite is in strong contrast with their abundance in the gabbro. We see a corresponding difference in Rum between the granite to the west and the peridotite and eucrite groups farther east. The latter do not differ greatly in this respect from the Torridonian, at least if we allow for the probability that some proportion of the dykes in the ultrabasic rocks have escaped detection. In the Torridonian itself, along the eastern coast of the island, it is noticeable that the shales in general contain more dykes than the succeeding sandstones.

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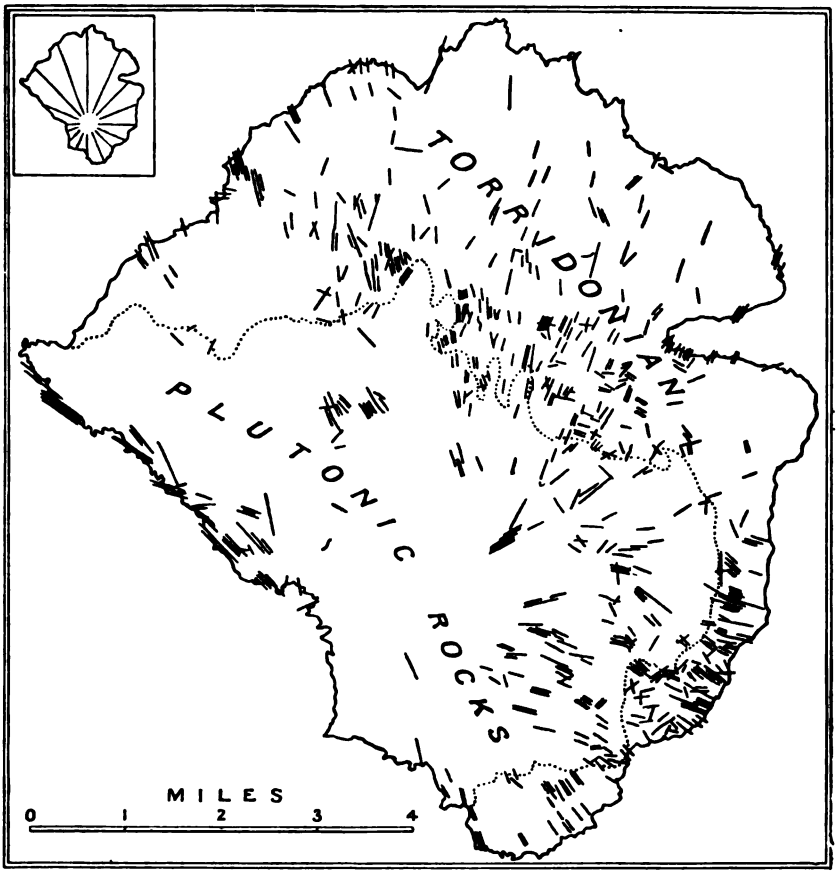
* *Tertiary Igneous Rocks of Skye*, p. 292.

Secondly, the geological habit of the plutonic intrusions exercises a very decided influence upon the number of dykes which succeed in penetrating the rocks. In the eastern part of the tract, from Allival to Sgùrr nan Gillean, where the peridotites, allivalites, and eucrites lie in stratiform masses with gentle inclination, the basic dykes are found in force. Farther west, where like rocks occur with more irregular relations, partaking in places of the boss-like habit, dykes are few. On part of the northern border of the ultrabasic tract, between Minishal and Loch Gainmhich, where the peridotite and eucrite cut nearly vertically across the Torridonian, very few of the numerous dykes in the latter have penetrated the former; but where this abruptly transgressive junction gives place to a gently overlying one the dykes have passed freely through.

Thirdly, the large tract of Torridonian strata, mostly of very uniform lithological characters, enables us to observe the distribution of the dykes in a single country-rock, and we see in this unmistakable indications of a ruling condition. To the north and north-east, remote from the mountains, dykes are found only sparingly; but as we approach the border of the plutonic tract, and especially of the ultrabasic groups, the frequency of dykes increases rapidly; and it is on this bordering belt of ground that most of the basic dykes of Rum are gathered. In other words, the dykes are most numerous towards the plutonic centre of the island. Their connection with the plutonic intrusions is, of course, not one of immediate common origin; for the dykes are of basic composition, the plutonic rocks mostly of ultrabasic (and in part acid). We may suppose rather that the localisation of the stresses which were relieved by these several outbursts followed similar lines; so that what had been a plutonic focus during one phase of activity continued to be a focus of special energy during the succeeding dyke-phase.

The relation thus indicated becomes more manifest, when we regard not merely the local distribution of the dykes, but their directions. As seen on the map (Pl. III.), they have a very general *radiate arrangement.* Passing from the westerly to the northerly headland of the island, and thence along the eastern side to Papadil in the south, we find the direction of the dykes gradually changing until it has swept through half the circle. In the other half of the circle, towards the south-west, the radiate disposition is less evident, partly from the fewness of the dykes, [illegible]artly perhaps for another reason. The dykes, it may be observed, [illegible]diate, not from the centre of the island, but from the centre of

PLATE III.



Sketch-map showing the distribution of basic dykes in Rum.

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the tract of plutonic rocks; the boundary of this tract (neglecting complications) being roughly indicated by the dotted line on the map. The idealised arrangement is suggested on the small sketch-map in one corner of the plate, and the point which most nearly corresponds with the ideal centre of radiation is situated some distance north of Loch Fiadh-innis.

In the Isle of Skye* it has been pointed out that, not only do the basic dykes become extremely numerous in the neighbourhood of the large intrusion of gabbro; but round the plutonic centres, both of gabbro and of granite, they show a certain regular departure from their general parallelism, tending somewhat towards a radiate disposition. Further, there is round the gabbro centre a special local set of dykes, in which the radiation is more strongly marked. We may therefore inquire whether, in what we have described in the case of Rum, we have to do with dykes of regional distribution influenced in their behaviour by local crustal strains, to which the plutonic intrusions were also related; or whether, on the other hand, all the basic dykes of this island belong to a special set of restricted distribution. The latter supposition is not supported by any direct evidence, and general considerations would lead us to expect that local groups of dykes connected with this centre would be for the most part not basic but ultrabasic. We may note too the rarity in the Rum mountains of the remarkable "inclined sheets" of dolerite which are associated with the special set of radiate dykes in the Cuillins. In the latter district too we find the regional series of dykes, with their characteristic tendency to one uniform direction, as well as the radiate set; while no such distinction can be drawn in Rum. We may therefore infer with much probability that the basic dykes here belong to the general regional series, while their increasing frequency and their radiate disposition are due to the disturbing influence of local causes. This disturbing influence has been a very powerful one. Whereas in Skye it produced only a certain degree of deviation from the general law of parallelism of the regional dykes, in Rum it entirely subverted that law.

An exception is, however, to be noted in the dykes which intersect the granite on the west coast of the island, between A' Bhrìdeanach and Harris We have already remarked that this strip of ground is exceptional in the number of dykes found in a country-rock of this nature. Of these dykes a few conform more or less nearly with the general law of radiation proper to the island; but the majority run parallel to the coast, in directions not differing much from north-west–south-east. It would appear that in this district the disturbing influence residing in the plutonic centre broke down, and the larger law of general parallelism characteristic of the region reasserted itself.

In other parts of the island exceptions to the radiate arrangement are not numerous. They sometimes present themselves in connection with a curved course and other signs of casual irregularity. Most of them, however, seem to fall under a subsidiary rule, for they tend very generally to be at right angles to the regularly oriented dykes in their neighbourhood. In other words, we see indication of a tangential set of dykes, conjugate to the radial set.

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* *Tertiary Igneous Rocks of Skye*, pp. 300, 301, 431, 364.

The basic dykes of Rum do not often show a very pronounced hade. Where this is noticed among the radial dykes, there is no apparent law governing the direction of hade. Among the north-west–south-east dykes of the granite cliffs several incline downward to the north-east, agreeing with the general law of hade in the regional dykes of Skye.*

Canna and *Sanday* are remarkable for the *relative fewness* of their dykes. Only eight were noted in the course of the survey; while Muck, with less than half as large an area, has perhaps twenty times as many. For a tract of this extent, composed of basaltic lavas and dolerite sills, and of the lower portion of that group, the comparative paucity of dykes is probably without parallel in the region.

We can scarcely hesitate to connect this peculiarity with the other feature in which Canna and Sanday are unique among the Inner Hebrides, viz., the great thickness of coarse volcanic agglomerate and conglomerate which here forms the lower part of the succession. It has been observed elsewhere† that these rocks are of an extremely refractory nature with reference to the passage of dykes; and both in Canna and in Sanday we have very remarkable illustrations of the manner in which the volcanic agglomerate arrests sill-formed intrusions. The fewness of dykes in these islands seems therefore to find an adequate explanation in the interposition of this thick mass of relatively impenetrable material. Further, we may reasonably argue backward from the scanty distribution of dykes to the inference that the volcanic agglomerate so conspicuous in Sanday and the eastern half of Canna is prolonged below sea-level under the western portion of the latter island.

Of the few dykes noted, half the number have the regular direction, N.W.–S.E. or N.N.W.–S.S.E., while the rest follow various courses.

The basic dykes are well represented on the *Isle of Eigg*, and in some parts become quite numerous. The observed distribution on the map is partly connected with the dying out of many of the dykes in the upward direction, from which it results that more are seen on the lower ground than on the higher. With rare exceptions, the dykes follow the general regional direction, bearing north-west or somewhat north of north-west. The special influence which modified this general parallelism in Rum does not make itself manifest in Eigg. Most of the dykes have a width of from one or two feet to six feet. The only very large one observed is some 300 yards east of the precipitous termination of the

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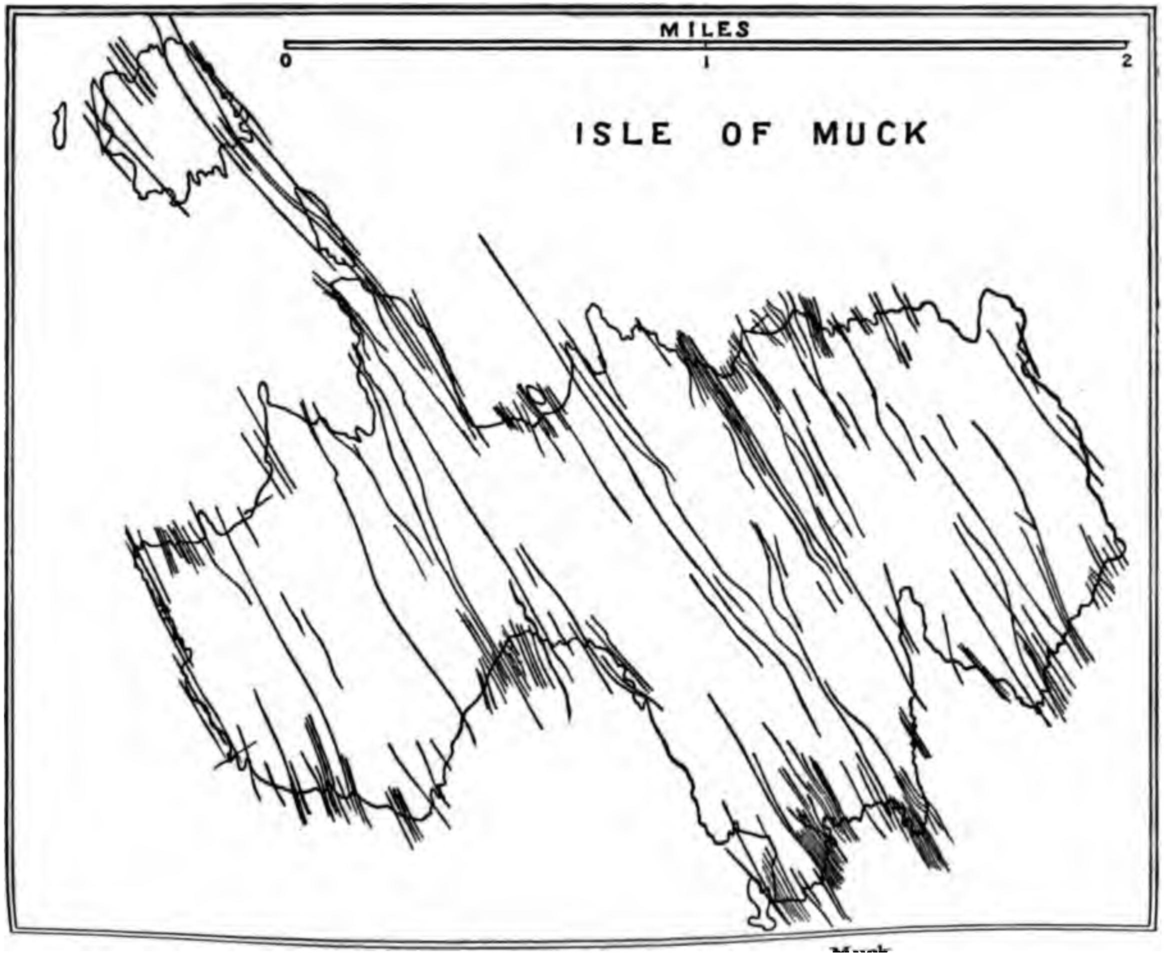
* *Tertiary Igneous Rocks of Skye*, p. 305 (1904).

† *Tertiary Igneous Rocks of Skye*, pp. 293, 294.

PLATE IV.



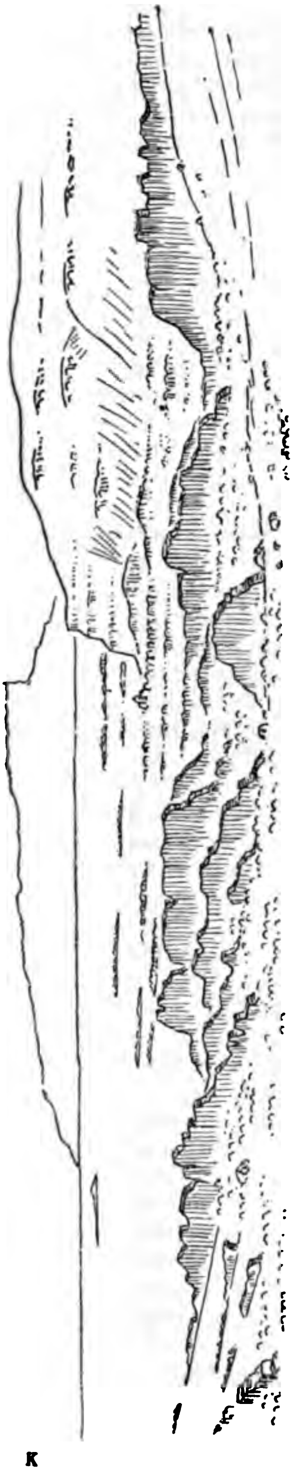


Fig. 41.—Basic dykes running out to sea; on the north coast of Muck, looking towards Eigg.

Sgùrr. This has a width of 70 feet, but cannot be followed for more than a short distance along its length. It is perhaps the only representative in the Small Isles of the large "solitary" dykes of coarse diabase met with in various parts of Skye.*

The most remarkable feature of the *Isle of Muck* is the *extraordinary number of basic dykes* intersecting the basaltic lavas and dolerite sills which build the mass of the island (Pl. IV.). Some particulars may be worthy of record. Between Camas Mòr and Port Mòr 40 dykes were mapped, with an aggregate width of about 165 feet. Since the distance measured at right angles to the direction of the dykes is 2350 feet, the dykes occur on the average at about 20 yards apart, and make up quite $\frac{1}{15}$ of the total rock as seen at sea-level. Along the whole southern and eastern coasts 134 dykes were mapped with an aggregate width of 535 feet, the average width being as before four feet. The distance, taken at right angles to the trend of the dykes, is 11,500 feet. The calculation gives therefore one dyke in every 28 yards, and the dykes make up $\frac{1}{21}$ of the total rock. These figures are probably under-estimates, for it may safely be assumed that some dykes have escaped notice.

There is no part of the island which does not show numerous dykes; but, as exposed on the coast, they are especially closely crowded in some places. (See fig. 41.) They make more or less salient features, and notably so in the cliffs and on the foreshore. The only notable exceptions to this observation are a few dykes which traverse a hard and rough volcanic agglomerate (fig. 42). The remarkable abundance of basic dykes in this island, remote from any notable plutonic centre, finds at least a partial explanation in observations elsewhere made on the different penetrability by dykes of different country-rocks. The dykes seen on the coast of Muck have in no case had to traverse many alternations of basaltic lavas and thick dolerite sills. The base of the basalt group, exposed at high-water mark in Camas Mòr, cannot be far below sea-level in any part of the island; and, so far as our information goes, the underlying Jurassic strata are not fortified, as they are in Eigg, by numerous massive sills of dolerite. Only one irregular sill or sheet is seen in the section visible. In confirmation of this explanation we may remark that many of the dykes die out rapidly in an upward direction. (See fig. 7, above.) Of the large number seen on either coast only a small proportion can be followed across the island, or indeed traced far inland. Moreover, most of those actually observed in the interior were noted, not on the hills, where the rocks are well exposed, but on the lower ground, although this is pasturage and arable land.

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* *Tertiary Igneous Rocks of Skye*, p. 320 (1904).

The mapping of the basaltic plateaux of Skye has already shown that, while dykes enter the lower portion of the basalt group sometimes in great numbers, they do not readily penetrate any very great thickness of the rocks. This appears perhaps more strikingly in the comparatively flat island of Muck, where even at the highest point the thickness of lavas and sills exposed is only 450 feet. The dying out upward of the dykes has been ascribed in Skye to the resistance offered by the massive sills of dolerite intercalated among the basaltic lavas*; but this conclusion is perhaps open to reconsideration. It may be that the inelastic nature of the partially decomposed amygdaloidal lavas makes them yield less readily to the formation of dyke-fissures than the sills, which have in all cases a tendency to vertical jointing; or the repeated alternations of these two different rocks may be a factor militating against the free passage of dykes. This seems the more probable in view of the fact that in the Cuillin Hills the dykes have freely penetrated 3000 feet of gabbro, a rock which, though hard and tough, is of sufficiently uniform character, from this point of view, from bottom to top.

Throughout the Isle of Muck, removed from the disturbing influence of any plutonic centre, the dykes follow the *regular regional direction;* and the map of this island presents a striking illustration of the strong tendency to a common *parallel orientation* which is so characteristic of our Tertiary dykes in these circumstances (Pl. IV.). The average direction is about N. 30° W.–S. 30° E., though deviations to the extent of 10° are found on either side of this line. A closer parallelism links together the dykes in any one locality, and intersections are not often to be observed. Where they occur, it is usually between dykes of different petrographical groups, and is often due to one of the dykes pursuing locally a curving course. Only three or four

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* *Tertiary Igneous Rocks of Skye*, p. 293 (1904).

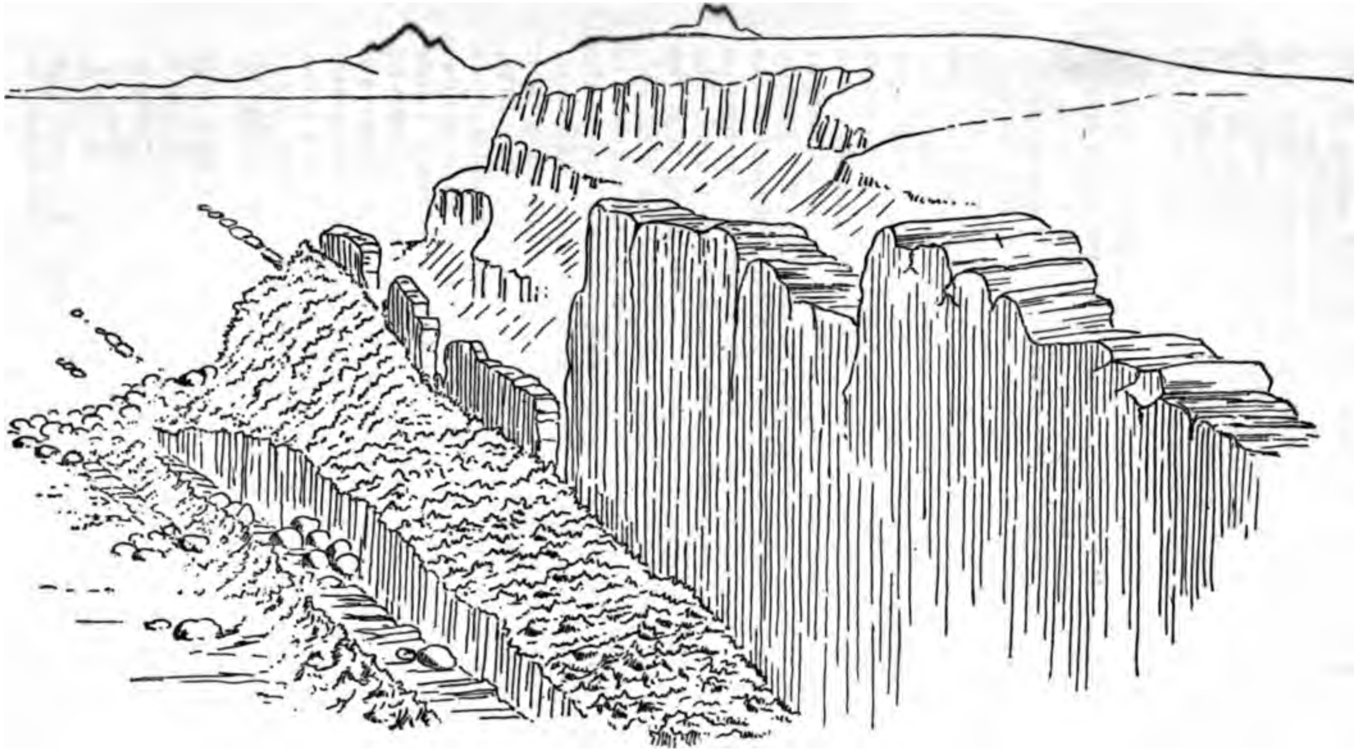

FIG. 42.—Basic dykes at Rudh' a' Chroisein, on the east coast of Muck. The large one to the right makes a strong wall-like feature, and also illustrates the common mode of jointing, roughly prismatic and perpendicular to the bounding surfaces. The dyke to the left traverses a hard and tough volcanic agglomerate, with a peculiarly rough weathered face, and here differential weathering causes a trench instead of a wall.

examples were noted on Muck of dykes quite discordant to the general law of direction, and these are at right angles to the regular bearing. They are intersected by the regular set.

The great number of dykes displayed on the coast of Muck, and the fact that they stand prominently out, making walls often twenty or thirty feet high, afford an opportunity for the study of some questions bearing on the behaviour of basic dykes in general; and some of the more interesting points may be deemed worthy of record.

In the first place, there is everywhere clear evidence that the flow of the intruded magma in the dyke-fissure was not in general vertically upward, but was in great measure directed along the length of the dyke. In other words, *the magma rose obliquely in the fissure*, following a direction between the vertical and the horizontal, and often nearer to the latter than to the former. A like result was found in Skye, both by Mr. Clough's study of the trachytic dykes and by observations on some of those of basic composition.* Throughout the greater part of Skye, however, the basic dykes tend to weather into trenches; and the better exposures on the coast of Muck allow a more complete examination of the question. On the walls of those dykes which have chilled margins the lines of flow are often well shown, and this is especially the case where a selvage of tachylyte is found. Sometimes the orientation of porphyritic felspars and the direction of elongation of amygdaloidal cavities afford information of the same kind. The flow-lines in different cases make angles from 0° to 80° with the horizon, the average of a large number of observations being 35°. The inclination may be in either sense, *i.e.*, north-westward or south-eastward. An attempt to establish particular foci as the sources of particular groups of dykes encounters some difficulties. At a given locality dykes evidently belonging to one group show a general agreement in the direction of their flow-lines. Thus, on the coast at Ard nan Uan, a set of dykes with tachylytic crusts (belonging to a peculiar type to be noticed below) gave inclinations 75°, 55°, and 62° to north-west; while an ordinary basalt dyke associated with them gave 42° to south-east. In different parts of the island, however, dykes petrographically similar are sometimes seen to have their flow-lines inclined in opposite directions. Along the length of a dyke, as exposed at a given locality, the inclination of the lines sometimes varies considerably; and there are examples which show a general horizontal movement with minor undulations.

We may notice next certain irregularities in the behaviour of dykes. A slight hade from the vertical is not uncommon, but it rarely exceeds a small angle. The inclination is in general downward to north-east, as has been observed also in Skye. A variable hade in a dyke is accompanied by a somewhat curved or sinuous course in ground-plan. These characters are sometimes connected with the dying out of a dyke; but they also depend in part on the petrographical type, being found less in ordinary basalts and dolerites than in certain special rocks richer in alkalies. Apparent interruptions of continuity and displacement of the course of a dyke are not infrequently seen. Especially common is the case in which a dyke, as seen in the ground-plan, is abruptly offset for a few feet, to resume its course in a parallel line, usually *en echelon*. The two parts are often connected by irregular veins or strings.* More striking is the displacement of the course of a dyke at a definite bedding-plane. This happens only in well-bedded strata, and is therefore confined in Muck to dykes traversing the Oolites. One of these may be suddenly arrested at a certain plane, pass along the bedding for some little distance with the regular habit of a sill, and then, with equal abruptness, resume its course as a dyke (fig. 43). Since the flow in these dykes is rarely in a vertical direction, and since the sill does not so easily spread laterally as the dyke, it happens that the two parts of the dyke may extend considerably beyond the limits of the connecting sill. A section may thus show the two parts of the dyke, one terminating upward and the other terminating downward at the same bedding-plane, without any visible connection (fig. 44). Dykes with this curious appearance, "*flat-topped*" and "*flat-bottomed*," have been noted in the Henry Mountains of Utah by Gilbert,† who has given a like explanation of the phenomena. A remarkable group of dykes of this kind is seen on the shore at Camas Mòr. The amount of shifting varies in different

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* *Tertiary Igneous Rocks of Skye*, pp. 294, 337 (1904).

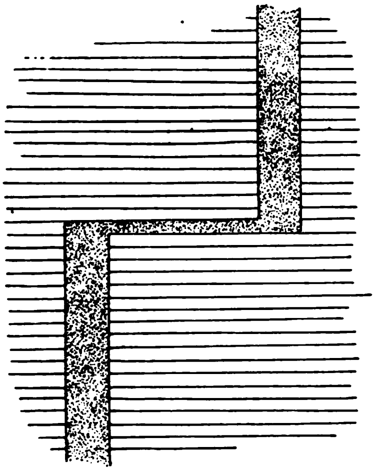

FIG. 43.—Diagram of a dyke shifting its course at a certain bedding-plane. (Vertical section.)

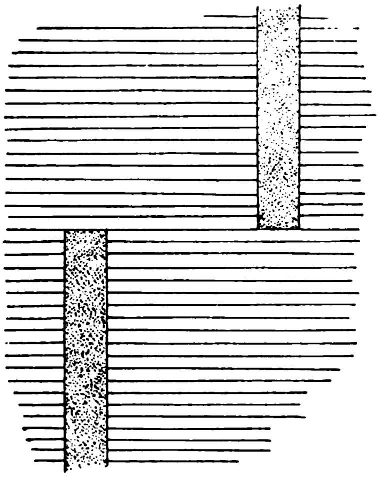

FIG. 44.—Diagram of flat-topped and flat-bottomed dykes, arising from shifting as before. (Vertical section.)

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* Compare *Tertiary Igneous Rocks of Skye*, pp. 303, 304 (1904).

† *Geology of the Henry Mountains*, pp. 28, 29 (1879).

cases from 6 to 40 feet. In some cases it is eastward—i.e., the upper half of the dyke is on the east side of the lower—in other cases it is westward. Of six examples which are clearly exhibited in spite of the numerous large boulders on the shore, two show the connecting sill, while in the others the upper and lower portions appear as if quite disconnected (fig 45). The horizontal surface at which each is arrested is smooth and flat, or only very slightly convex, and is continuous with the surface of the connecting sill where such is seen. The country-rock here is the *Ostrea hebridica* group, consisting of alternations of oyster-beds and shales; and, in the cases which can be easily examined, the several dykes are shifted at the same horizon, a bed of shale not differing in appearance from the rest. By reaction with the substance of the shales, the dykes are to some extent decomposed to the so-called "white trap," and contain a large amount of calcite. They all belong to one petrographical type, and dykes of other kinds in the neighbourhood do not show a like displacement.

As a rule a dyke preserves a fairly constant width throughout its visible extent; but there are cases in which a dyke gradually tapers and dies out, and this may occur in the downward direction. A good example occurs at Rudh' an Inbhire, on the west coast of Muck. Here a large dyke of coarse diabase swells out to a great width in the upper part of the cliff, while downward it becomes much attenuated and disappears. This is another effect which is to be explained only by recognising that the propagation of the magma in the dyke-fissure must have been more nearly horizontal than vertical.

(ii.) GENERAL PETROGRAPHY OF THE BASIC DYKES.

The basic dykes of the Small Isles exhibit a certain range of petrographical variety. A comprehensive account of the several types and their distribution would demand an extended study, and it is doubtful whether it would lead to any results of general interest or novelty. Our description will therefore be of a summary kind, and only a few characteristic examples will be cited. While some of the differences observable in specimens are to be referred to the circumstances attending the intrusion of the several dykes (the larger ones, for instance, being usually of coarser texture), there is also some mineralogical diversity which points to real differences of composition among the intruded magmas. A thorough study of the rocks, accompanied by a sufficient number of chemical analyses, might enable us to divide them into distinct groups, which we might suppose to belong to different epochs of intrusion.

That here, as in Skye, the numerous assemblage of Tertiary dykes is referable, not to one, but to numerous distinct epochs in the history of igneous activity, does not admit of doubt. It is not, however, practicable to separate satisfactorily the several natural groups and range them in their proper places in the succession. Owing to the general parallelism of the dykes at any given locality,

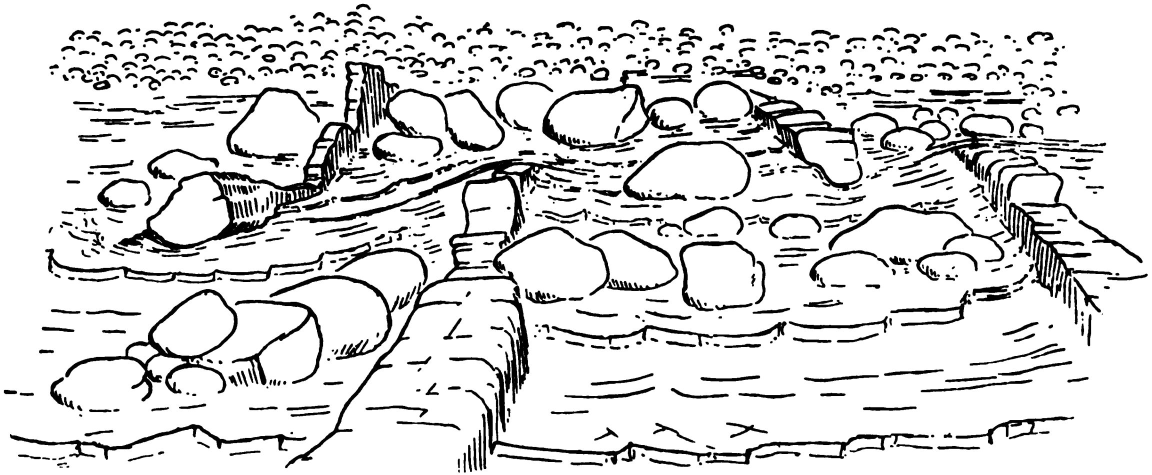

FIG. 45.—Flat-topped and flat-bottomed dykes between tide-marks at Camas Mòr, Muck; looking inland (northward).

The four dykes are in reality only two, each of which has its upper half displaced to the left (westward).

intersections are rarely to be observed: and the relations of the dykes to other intrusive rocks (laccolitic and stratiform) affords only fragmentary evidence on this point. We have already pointed out that some of the dykes belong to the volcanic phase of activity, and represent the feeders of the basaltic lavas. The majority, however, are certainly post-plutonic, and belong to various epochs of the phase of minor intrusions. Most of them, at least, are younger than the dykes and sheets of quartz-felsite and granophyre; and probably all the basic dykes (setting aside certain ultrabasic ones) are older than the pitchstones to be described below. Between these limits there may be represented a very considerable extent of time, during which different groups of basic dykes were intruded in a succession which we have not been able to ascertain.

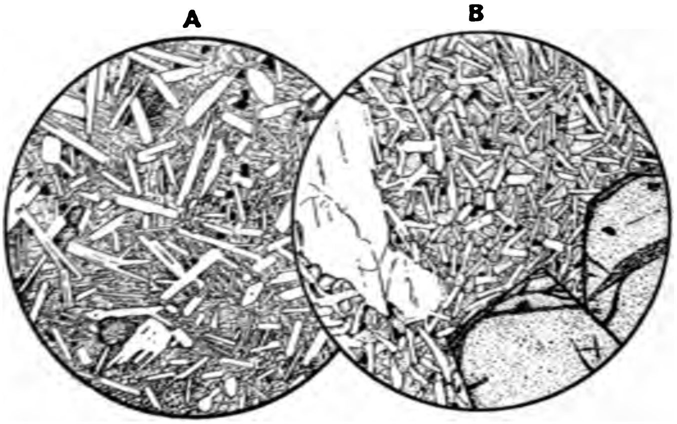

FIG. 46.—Basic dykes; × 20.

A. [11,704].—Olivine-Dolerite, Camas Mòr, Muck. The olivine is represented only by pseudomorphs. The structure is ophitic.

B. [11,703].—Porphyritic Olivine-Dolerite, Rudha na Crannaig, Kildonan, Eigg. The porphyritic elements are olivine and labradorite. The augite has the granulitic habit.

The essential minerals are the same in the basic dykes as in the basic sills—a plagioclase felspar; augite, showing a pale-brown colour in thin slices; magnetite; and usually olivine. There is, however, a somewhat greater range of variety among these rocks. In some olivine is wanting, and the felspar belongs to the less basic half of the plagioclase series. This type is represented, for example, by a number of small dykes near the roadside in the neighbourhood of Dornabac, Rum. They are *ophitic dolerites*, without olivine but with abundant magnetite [11,701]. Most usually, however, olivine is present in greater or less amount, either in a fresh state or replaced by green serpentinous pseudomorphs. Ophitic olivine-dolerites, with a medium labradorite as the felspathic element, are a common type, and are represented, for instance, among the numerous dykes of Camas

Mòr, in the Isle of Muck (fig. 46, A). These rocks are usually of medium texture, the felspars being large enough to show repeated albite-lamellation, as well as carlsbad twinning and occasional traces of the pericline law. The same type is frequent on Eigg.

Many of the dykes, perhaps the majority, have a more or less noticeable porphyritic character, the conspicuous elements being rectangular felspars and sometimes crystal-grains of olivine. *Porphyritic dolerites* without olivine are found in several places, and some dykes of this type stand out prominently from the decaying eucrite of Coire Dubh, in Rum. Here the augite has a tendency to idiomorphism, and the magnetite often assumes skeleton forms. The felspar often varies in composition in concentric shells, giving the well-known zonary banding between crossed nicols, and in such cases the outer shells are always of more basic composition than the interior [11,702].

Porphyritic olivine-dolerites and *olivine-basalts* are found in considerable variety. One very noticeable type is represented by a prominent dyke near Kildonan, Eigg. This shows grains of olivine about an eighth of an inch in diameter, as well as porphyritic crystals of a basic labradorite with zonal structure. The augite here has the granulitic habit (fig. 46, B). A different type is represented by the porphyritic basalt dykes on Beinn a' Bhàrr-shaibh, Rum. Here the porphyritic felspars, half an inch in length, are of anorthite [10,505]. There are other cases in which the felspar is also of a very basic variety. If, in the neighbourhood of a plutonic centre, some of the dykes belong to local groups which may in some sense be correlated with the plutonic magmas previously intruded at that centre, we should expect to find in Rum dykes having some of the characteristics of the eucrites; but we have not detected in any of the dykes of this island the presence of rhombic pyroxene, which is so frequently a feature of the neighbouring eucrite intrusions.

Among the basic dykes of the Small Isles there are a few, especially on Muck, which in some of their features recall the special characters of the *mugearite type.* This affinity is seen in the coming in of the less basic felspars (andesine and oligoclase, and probably in some cases orthoclase), in a diminished proportion of augite relatively to magnetite and olivine, and rarely in the presence of minute flakes of a brown micaceous mineral, which may possibly be that described from the typical mugearites of Skye.

(iii.) OCCURRENCE AND PETROGRAPHY OF TACHYLYTES.

In general the normal basalt and dolerite dykes of the British Tertiary region contain little or no glassy residue, contrasting in this respect with the augite-andesites intruded at a later epoch. If any glassy base is present, it is usually confined to, or more richly found in, the marginal parts of the dykes, and there may be an essentially vitreous selvage, often not exceeding a fraction of an inch in width. These *selvages of tachylyte* have been studied by more than one petrologist,[*] and it has also been noted[†] that in certain cases the whole width of a small dyke has a more or less glassy composition. This latter peculiarity was observed in dykes which were either shown or suspected to have affinities with the mugearite type. Dykes with tachylytic selvages are unusually numerous on the Isle of Muck; and the manner in which they stand out like walls on the shore and in the cliffs makes them especially suitable for study. We shall accordingly give some observations made under these favourable conditions.

Some twenty or thirty tachylytic dykes were examined on the coast of Muck. In many of them the selvage of lustrous black glass is a mere skin, $\frac{1}{20}$ to $\frac{1}{10}$ inch in thickness, and gives place rather rapidly to the dull compact or fine-textured interior; though the microscope shows that the latter also contains a considerable amount of glassy base for perhaps a couple of inches from the edge. The tachylyte has much of the appearance of coal, and the actual surface, as exposed on the wall-like face of a dyke, often shows an irregularly wrinkled and finely fissured aspect. Again, there is often a fine striation, which is a flow-structure, and, as already remarked, may make quite low angles with the horizontal.

In a somewhat different type the crust of tachylyte is perhaps a quarter of an inch thick, and shades gradually into the less perfectly glassy interior, the lustre on a broken surface passing insensibly from the vitreous (or obsidian-like) to the resinous (as in some pitchstones), while the central part of a thicker dyke appears as finely crystalline. A fine group of dykes of this type, with marked flow-lines on the walls, may be seen in the low cliff on the east side of Ard nan Uan, the north-westerly peninsula of Muck. They are four or five in number, and range from a foot to nine feet in width. Two similar dykes are well exposed immediately on the west side of Port Mòr. The walls of some of these dykes are not quite plane, but show broad gentle undulations. There is often a tendency to exfoliation in the marginal part of a dyke; so that the crust, to the thickness of two or three inches, is easily picked off.

At two or three localities a more remarkable development of tachylyte is found. One example is a dyke on the shore of Camas Mòr, a little west of the headland which projects into the middle of the bay. Here there is a thickness of six to eight inches of black glass. It is found only on the eastern edge of the dyke (some two feet wide), where it is in contact with an older dyke of crystalline dolerite. We must suppose that the latter rock, a relatively good conductor of heat as compared with semi-decayed amygdaloidal basalts and most sedimentary deposits, facilitated the rapid cooling of the magma which was injected in contact with it, and so caused it to solidify in the glassy form. It has already been remarked in Mull[‡] and Skye[§] that noticeable selvages of tachylyte are found especially where the dykes traverse the dolerite sills rather than the basalt lavas. A more striking illustration of the same principle is seen in a dyke at Camas na Cairidh, on the north coast of Muck. This dyke, as actually exposed, consists of two detached portions (see ground-plan, fig. 47), which are doubtless united at a greater depth. They penetrate from opposite sides an earlier dyke of dolerite, which traverses the amygdaloidal basalts, the whole being well exhibited on the shore of the little inlet. That part of the younger dyke which cuts the basalt is about 1½ to two feet in width, with bounding walls of slightly undulating form, and with strongly marked exfoliation of the kind already noticed. There is in this part no tachylyte selvage. Where the more easterly of the detached parts cuts the dolerite, however, a crust of tachylyte appears on both sides, and this becomes thicker as the dyke thins away and dies out in the heart of the dolerite. The termination of this part is a tongue of black glass, five or six feet long and six inches or more in width. A similar effect is seen where the other (westerly) part of the newer dyke enters the dolerite and dies out in it, except that the mass of tachylyte which makes the termination has in this case a highly irregular shape. With this Camas na Cairidh dyke and the one noticed in Camas Mòr may be classed also two small ones seen close to Gallanach, on the south-west side of the rock (an islet at high tide) in the bay. These dykes, only 1 to 1½ foot wide, show a thick glassy selvage passing into a pitch-like interior, but where they thin away the whole width becomes glassy.

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[*] Judd and Cole, *Quart. Journ. Geol. Soc.*, vol. xxxix., pp. 444–464 (1883). Cole, *ibid.*, vol. xliv., pp. 300–307 (1888). Heddle, *Trans. Geol. Soc. Glas.*, vol. x., pp. 80–95 (1895). Harker, *Tertiary Igneous Rocks of Skye*, chap. xix. (1904).

[†] *Tertiary Igneous Rocks of Skye*, pp. 335, &c.

[‡] Kendall, *Geol. Mag.* (1898), p. 55.

[§] *Tertiary Igneous Rocks of Skye*, p. 334 (1904).

That those dykes which exhibit an unusual development of tachylyte have affinities with the mugearites is borne out by the relatively *low density* of the glassy selvages. In Skye it was found that examples of this kind usually gave specific gravities from 2·65 to 2·75, as compared with 2·76 to 2·92 for true basalt-tachylytes. Some of the Muck dykes mentioned above give equally low figures—

Port Mòr, - - - - - -	2·64
Camas Mòr, - - - - -	2·60
Camas na Cairidh, - - - -	2·56
Gallanach, vitreous selvage, - -	2·69
Do., resinous interior,. - -	2·72

With these may be contrasted a dyke at Caisteal an Duìne Bhaìn, with only a thin selvage of glass—

Tachylyte of selvage, - - -	2·945
Basalt of interior, - - - -	2·893

It will be seen that, not only is the rock in this case much denser, but the glassy selvage is denser than the more crystalline interior. This peculiarity is highly characteristic of the basalt-tachylytes.

The *micro-structure of the tachylytes* of Muck has been studied in more than thirty thin slices. The thin skins of tachylyte which

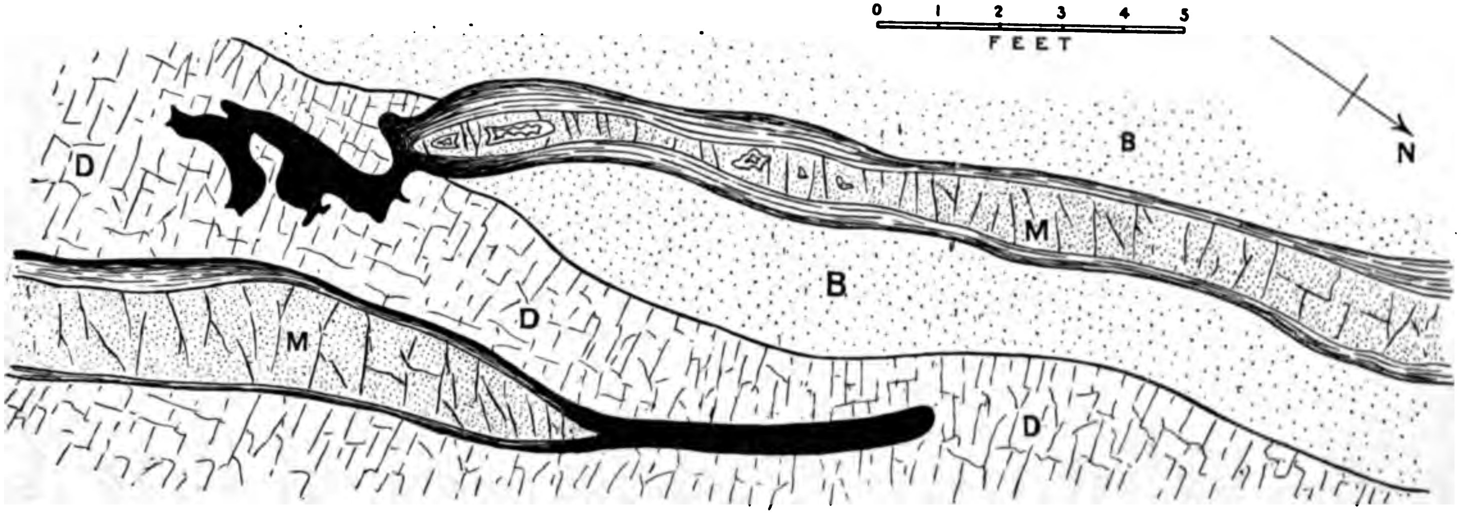

FIG. 47.—Ground-plan of dykes on the shore at Camas na Cairidh, on the north coast of Muck.

B.—Amygdaloidal basalt lavas. D.—Dyke of crystalline dolerite.
M.—Dyke (in two detached portions) with exfoliating margin. The part shown black is tachylyte.

may be taken to represent normal basalt-glass were examined from a number of dykes in the neighbourhood of Gallanach, Camas na Cairidh, Rudh' a Chroisein, Port Mòr, Camas Mòr, and Sròn na Teis. The general characters are very similar in the several occurrences. Most of the rocks are micro-porphyritic, the dimensions of the porphyritic crystals varying in different examples. The felspars are often about ·01 inch long. with albite-twinning, and with the extinction-angles of labradorite. Olivine, either fresh or as serpentinous pseudomorphs, is in good crystals, the smaller ones with skeletal shapes or with relatively large glass-inclusions. Magnetite crystals are constantly present, and often granules of augite. These micro-porphyritic elements are, as a rule, fairly evenly distributed in the interior of the dyke and the glassy selvage alike, the marginal modification affecting only the ground-mass. In some cases the crystals, though present in the tachylytic selvage, occur there more sparingly than in the interior. At an inch or more from the actual wall of the dyke, although there may be no perceptible vitreous lustre, the ground-mass consists very largely of brown glass. It encloses abundant slender crystals of felspar, minute octahedra of magnetite, and sometimes granules of augite. The felspars, from ·001 to ·005 inch long in different examples, often have forked extremities, or contain a central core of glass. Nearer to the edge of the dyke these crystallitic elements become sparser and more minute, and at the actual edge they are usually absent. The ground-mass then consists essentially of brown glass. In this there sometimes appear small round spots of a deeper tint, practically opaque, and these, becoming more numerous, coalesce until they fill the whole space. There may still be, at the actual edge, a very narrow sharply defined band of clear yellow-brown colour, and this is also seen in the little irregular tongues which occasionally penetrate the contiguous dolerite.

Although flow-lines are often apparent in the selvages, there is no strongly marked banding, with different micro-structure in successive narrow bands. In this, and especially in the absence of micro-spherulitic structures, these basalt-tachylytes from Muck differ from some of those described from Skye, Mull, and County Down. A regular perlitic fissuring is seldom found; but there are often irregular cracks, and along these there is in one or two cases an incipient devitrification.

The dyke at Caisteal an Duìne Bhaìn, already mentioned, differs in some respects from the foregoing. The light-brown ground-mass is in some parts a clear glass, but in others (not at the actual edge) it is crowded with excessively minute fibres of felspar. These are partly disposed in radiate and sheaf-like fashion, and show between crossed nicols an imperfect and fragmentary black cross. In this rock, both in the tachylytic selvage and in the less glassy interior, there are highly corroded crystals of felspars, including orthoclase, which may be regarded as "xenocrysts." They occur also in the similar dyke of Am Bile in Skye.

There remain the rocks which, with regard to their low specific gravity and the comparative readiness with which they assume the glassy form, we have separated from the normal basalt-tachylytes, and for which we have suggested an affinity with the mugearites. The vitreous rocks of this kind described from Skye show characteristically a colourless or pale glass crowded with dark crystallites. Such is the nature of some examples from Muck; but others, notwithstanding their points of difference from the normal basalt-tachylytes already remarked, resemble these in their appearance under the microscope. Thus, the tachylytes of Ard nan Uan and the west shore of Port Mòr, and even the thick glassy crust of the dyke at Camas Mòr (with specific gravity 2·60), show a deep brown colour verging on opacity even in very thin slices, or sometimes a strong brown with darker (nearly opaque) spots, There may be, as before, a thin band of paler yellowish brown on the extreme margin. Micro-porphyritic elements are generally wanting. Microscopic vesicles, occupied by secondary products. may occur here, as in other tachylytes.

One only of the Ard nan Uan tachylytes differs from its associates, and resembles in micro-structure the typical mugearite-tachylytes of Skye. It shows a pale-brown glass crowded with crystallites, which are partly slender fibres of felspar, partly minute dark rods. A few rather larger crystallites of felspar show skeletal shapes with cores of glass. The dark rods tend to a regular disposition, parallel and at definite angles, forming portions of gratings. There are in addition some scattered minute octahedra of magnetite and a few little flakes of a brown micaceous mineral, the presence of which is significant.

The remarkable dyke at Camas na Cairidh (fig. 47) realises very closely the type of mugearite-tachylyte described from Skye.* The central part, without vitreous lustre, but of very compact appearance, shows under the microscope a yellowish cloudy base enclosing innumerable little rods with a partial parallel arrangement in interlacing groups (Pl. VIII., fig. 1, A). These seem to be of a decayed ferro-magnesian mineral, probably augite. There are also scattered microlites of felspar. With a higher magnification innumerable very minute octahedra of magnetite are seen, and the yellowish base is resolved into a densely packed aggregate of extremely fine felspar fibres with interstitial light-brown glass. The edge of the dyke shows very similar characters, except that, in addition to the rods of decayed augite, there are others of magnetite. These are seen under a high power to be minute granules or crystals like those in the former slide, but here arranged in lines. The pale-brown glass is now much more abundant. The solid mass of tachylyte, which makes the termination of each half of the severed dyke, has a different character. With a low-power objective the slice shows merely a colourless base densely charged with opaque dust. More highly magnified, the latter is seen to consist of minute granules of magnetite, while the colourless part is of glass enclosing a crowd of exceedingly minute felspars. The contrast with the ordinary basalt-tachylytes is very marked.

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* Allt Thuill, Loch Ashik, &c., *Tertiary Igneous Rocks of Skye*, pp. 348–350, pls. xxiii., fig. 1, and xxiv., fig. 1.

The rock of the small dykes at Gallanach has much in common with that just described, but presents also some points of difference. The appearance of the interior part (with resinous lustre) under high magnification is shown in Pl. VIII., fig. 1, B. The ferro-magnesian crystallites are here wanting, and, excepting scattered rods of felspar, the only conspicuous elements are slender rods of magnetite, grouped partly in the fashion of a rectangular grating, but also with something of a radiate arrangement. It may be remarked that both this and the preceding rock (like some in Skye) show in hand-specimens a very ill-defined spherulitic appearance. In a slice the areas of the spherulitic bodies are scarcely distinguishable, but sometimes the centre of such an area is slightly clearer than the rest, and has a few little felspar rods with radiate disposition, this and the vague arrangement of the magnetite being the only signs of any special structure. The general mass of this rock, enclosing the magnetite rods, consists of crowded felspars of very minute size and pale-brown glass, which has a tendency to accumulate in little patches. The edge of these dykes seems to be wholly of glass, and is of so deep a tint as to be practically opaque. We seem to have here a connecting link between the normal basalts and rocks of the type exemplified by the Camas na Cairidh dyke.

CHAPTER XIII.

LATER BASIC INTRUSIONS (RUM AND EIGG).

(i.) BASALTIC SHEETS.

In this chapter we shall notice very briefly certain intrusions, mostly of sheet-form and of distinctly basic composition, which in no case attain any extensive development. They belong to several distinct groups, referable to different epochs; but, so far as the evidence carries us, they may all be assigned to the latter part of the phase of minor intrusions. In the Torridonian tract of Rum it is not always possible to separate decisively these late stratiform intrusions from possible irregular representatives of the great group of dolerite sills, modified in habit by the nature of the country-rock; but, as already remarked, there is no clear evidence of the occurrence of the principal sill group at this low horizon, and the majority at least of the small basic sheets there met with appear to belong to later dates.

Certain rather irregular sill-formed intrusions of basic rocks in the Torridonian sandstone of the northern part of Rum are mostly thin sheets of very limited lateral extent. One, however, in the *neighbourhood of Kilmory* makes a conspicuous feature, and may be followed from Kilmory Lodge to Loch Sgaorishal. The western or north-western side of the feature shows an exposed dip-slope of the basaltic sill, in places from 100 to 150 yards in breadth. In one place a dyke, which seems to represent one of the feeders, is seen beneath the sill and communicating with it. The rock, which may be taken as a type of others in the neighbourhood. is finely jointed, and has suffered from weathering. A comparatively fresh specimen is a dark-grey rock containing numerous small felspars, about $\frac{1}{20}$ inch long, and it may be described as a porphyritic basalt or basic augite-andesite, without olivine. The small porphyritic felspars are labradorite, with carlsbad and albite twinning and some zonary banding. The ground-mass is of slender striated felspars and granules of augite, with some little octahedra of magnetite [10,501].

Certain intrusive sheets of basic rock on the *borders of the Rum mountains* are of interest in a comparison of the Tertiary igneous succession here with that in Skye. In the latter island the gabbro of the Cuillins is intersected by a vast number of *inclined sheets* of dolerite and basalt, belonging to a late epoch in the phase of minor intrusions. Their distribution, and the manner in which they are regularly inclined inward towards the centre of the large gabbro laccolite, make it clear that these sheets constitute in Skye a local group connected with the gabbro centre, though much younger than the plutonic rocks themselves.* Some indications of a corresponding group of sheet-formed intrusions are to be remarked in Rum; but they are here much less developed, and have not furnished such clear evidence of their exact age.

Basalt sheets which appear to belong to this group are numerous along an area bordering the northern side of the plutonic tract, especially north and east of Loch Bealach Mhic Neill and in the burns which drain Coire Dubh. These occur in Torridonian strata but others cut the plutonic rocks, and some intersect the porphyritic quartz-felsite. They are thus removed from the great group of sills, and must be assigned to a later date. They are described as sheets, not sills; for, when they occur in bedded rocks, they do not follow the bedding, but have an independent direction. About Loch Bealach Mhic Neill they dip south, usually at angles of about 20°; in Coire Dubh the dip is to south-west; while towards Loch Sgathaig the inclination becomes nearly south-east. There is thus a general dip inwards towards some point within the plutonic tract, this centre being indeed somewhere beneath the upper part of Glen Harris. The much more scattered sheets of this group met with in other places conform in inclination to the same rule. Thus on the easterly ridge of Askival the dip is to W.N.W. at 33°; about the coast near Dibidil it is north-west; on Ashval and Sgùrr nan Gillean it is nearly north at angles of 40° to 55°.

These sheets sometimes intersect basalt dykes, but no case of the reverse relation has been observed, and, so far as the evidence goes, they seem thus to be the latest group of basic intrusions in the proper sense. The individual sheets are never of great thickness and usually only a very few feet; though, when they occur in the Torridonian rocks, their smooth surfaces are sometimes exposed for a considerable width.

It has been remarked elsewhere, as a characteristic peculiarity of the British Tertiary intrusions, that the basic dykes and sheets in some parts of the region enclose numerous "*xenoliths*" of gabbro, and sometimes also of granite.† These particular foreign elements have nothing in common with the merely accidental inclusions picked up from the rocks through which the intrusions break; but stand in an intimate, if not yet explained, relation to the enclosing rock. So far as our observations go, the phenomenon is less common in the Small Isles than in Skye, but examples have been noted, especially in the Isle of Rum. A sheet of porphyritic basalt conspicuous at the fork of the roads to Harris and Kilmory contains abundant inclusions of gabbro. A xenolithic sheet of somewhat different character is seen in the face of the peridotite escarpment at the head of Glen Harris. In the basic dykes inclusions of eucrite or gabbro have been observed in only a few cases. Accidentally enclosed fragments of the contiguous rocks are sometimes to be noticed, *e.g.*, in some of the dykes which intersect the Oolitic strata of Camas Mòr in Muck; but this is not a striking feature of our dykes, excepting the special group which we have assigned to the volcanic phase. (See p. 66.)

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* See *Tertiary Igneous Rocks of Skye*, chap. xxi. (1904).

† *Tertiary Igneous Rocks of Skye*, chap. xx. (1904).

(ii.) SHEETS OF BASIC ANDESITE.

In the Torridonian sandstones of the southern part of Rum, east of Papadil, occurs a group of sill-intrusions of a rock which may be termed a basic augite-andesite, differing in important particulars from the basaltic Kilmory type. The sills, dipping north-westward with the sandstones, show some little breadth of exposed surface, and in the slope overlooking Loch Dubh an Sgòir they give rise to a noticeable feature. Two of the small sills cross the Rudha nam Meirleach fault without displacement, a fact sufficient in itself to prove that they do not belong to the great group of dolerite sills, but are of later age. It is probable that these intrusions, which we may distinguish as the *Papadil type*, belong to the "younger augite andesites" of Professor Judd, referable to one of the latest epochs in the history of Tertiary igneous activity.

The usual variety of the rock is of dark-grey colour, with the appearance of a fine-grained dolerite, and one specimen gave the specific gravity 2·842. A peculiar feature is the occurrence of numerous little spherical spots of finer texture about an eighth of an inch or more in diameter. These are sharply defined, and stand out on a broken surface. A few felspar crystals of somewhat larger dimensions than the rest give a certain micro-porphyritic character, not noticeable except in thin slices [11,717–8]. These are apparently andesine-labradorite. The slender "lath-shaped" felspars, which make up most of the rock, give lower extinction-angles, and may be set down as andesine or oligoclase-andesine. Augite is presumably represented by patches of chloritic and ferruginous alteration-products. In the interstices between the little felspars, and also occupying the round spots already mentioned, is a matrix of much finer texture. This consists mainly of very delicate felspar fibres, with some tendency to radiate arrangement, and with some rather larger felspar crystallites, which are hollow and have forked terminations. Augite is not to be recognised in this part, but magnetite is rather abundant, and assumes the form of minute rods. At the margin of a sill the whole rock assumes this fine-textured character, with the same forked microlites of felspar and little rods of magnetite. In its interstitial occurrence this matrix plays the part of the glassy base found in many of the younger augite-andesites of the region, and it is possible that it results from the devitrification of a residual glass. The round spots are undoubtedly vesicles filled at a late stage by the oozing in of the residual magma. The phenomenon is one highly characteristic of the late augite-andesite intrusions throughout the British area.*

A dyke, 15 or 16 feet in width, near Lochan nam Meirlach is probably one of the feeders of this group of intrusions. It has a W.N.W.-E.S.E. direction. It is a dark-grey rock with the appearance of a fine-grained dolerite, and microscopical examination shows that, allowing for a difference of texture, it has characters in common with the sills. The felspar is apparently an oligoclase-andesine; the augite, in minute shapeless granules, is not very abundant; and the magnetite, which is fairly plentiful, has a strong tendency to rod-like shapes [11,719].

A well-marked group of intrusive sheets, which we shall distinguish for convenience as the *Kildonan type*, is developed in the Isle of Eigg, and is specially conspicuous on the east coast, between Kildonan and Galmisdale Point. These sheets invade and entangle the Oolitic sandstones on the shore of Poll nam Partan, and cut indifferently across the basalt lavas and dolerite sills of Rudha na Crannaig. From here they can be traced for some distance past the graveyard and the ruined chapel of St. Donnan, and one is seen by the side of the road descending towards the shore. Similar sheets are seen on the headland south of Poll nam Partan and near the north pier, while others form the succession of reefs and rocky islets which lie to the north of Castle Island and embarrass the entrance to the harbour. The individual sheets are of no great magnitude, the smallest being only a foot or two in thickness; but the surfaces are exposed over considerable areas, and are conspicuous from the fact that they are usually coated with a crust of black glass. The sheets with glassy selvages noted by Mr. Tait near Clach Alaisdair, on the opposite coast of Eigg, probably belong to the same group; but they do not seem to have a wide distribution over the island in general; unless they are confined to a low horizon, and so concealed under the hills of the interior. The sheets do not conform, except locally, to the bedding of the lavas and the direction of the sills, and in some places they become for a distance so steeply inclined as to assume the habit of dykes.

These Kildonan sheets are manifestly younger than the dolerite sills, which they intersect, and they are also younger than the plateau-faults, which do not dislocate them. On the other hand, one of the sheets is seen to be cut by a pitchstone dyke at the north pier. The sheets belong then to a late, but not to the very latest, epoch. It is probable that they are of approximately the same age as the Papadil sills, just described, with which they have significant points in common as regards petrographical characters.

Excluding for the present the tachylytic selvages, the rock appears as a dark-grey or nearly black dolerite, of moderately fine crystallisation, without porphyritic elements. A specimen from the island-rock Eilean Feòir, east of the north pier, gave the specific gravity 2·840, agreeing nearly with the Papadil rock, while a specimen from near Kildonan gave 2·82. A rock from the latter locality has been analysed by Dr. Pollard, and the result is appended. Rejecting the carbonic acid and uncombined water, we may calculate the corresponding mineral composition to be approximately—

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* Teall (Tynemouth dyke), *Geol. Mag.* (1889), pp. 481-483, pl. xiv. Judd (Ardnamurchan), *Quart. Journ. Geol. Soc*, vol. xlvi., p. 378 (1890). Sollas (Donegal), *Sci. Proc. Roy. Dubl. Soc.* (2), vol. viii., p. 93 (1893). Harker (Skye), *Tertiary Igneous Rocks of Skye*, p. 400 (1904).

Felspar (near andesine),	49
Augite,	37
Iron-ores (titaniferous),	13½
Apatite,	0½
	100

The low acidity is connected, not with the nature of the felspathic constituent, but with the preponderance of the non-felspathic minerals; and this Kildonan type, like that of Papadil, finds its affinities among the basic andesites rather than among the basalts.

SiO_2	44·60
TiO_2	1·84
Al_2O_3	12·83
Cr_2O_3	0·02
V_2O_3	0·05
Fe_2O_3	4·65
FeO	8·26
NiO, CoO	0·04
MnO	0·37
MgO	6·43
CaO	10·95
BaO	not found.
SrO	trace ?
Na_2O	2·59
K_2O	0·31
Li_2O	trace ?
H_2O above 105°	0·70
H_2O at 105° C.	1·33
P_2O_5	0·20
CO_2	5·39
½S	0·24
	100·80

[11,733].—Dolerite, irregular intrusive sheet, shore south-west of Kildonan, Eigg : anal. W. Pollard.

A microscopic examination of the rocks bears out this conclusion. The constituent minerals are felspar, augite, and magnetite. The felspar shows elongated sections, about $\frac{1}{50}$ inch in length, with twin-lamellæ and with the moderately low extinction-angles of andesine or andesine-labradorite. The pale augite, of later crystallisation than the felspar, builds small crystal-grains, or may show some tendency to the sub-ophitic habit. The little grains of magnetite show more or less of the octahedral shape. It may be observed that here, as in others of our rocks, the chemical analysis shows a notable amount of titanic acid, though the only iron-ore present has constantly the form of magnetite. This accords with Vogt's supposition that there exists an orthotitanate, $2FeO, TiO_2$ (titanomagnetite) isomorphous with the orthoferrate $2FeO, FeO_2$ (magnetite), just as the metatitanate FeO, TiO_2 (ilmenite) is isomorphous with the metaferrate FeO, FeO_2 (hæmatite). In the present case the analysis seems to indicate that titanomagnetite and magnetite are present, in the form of "mixed crystals," in the proportion 3 : 4.

A glassy residue is present or absent in different specimens. Apparently the thicker sheets are holocrystalline in the centre, but contain more or less of a glassy base in their more marginal portions. The glass is of a light-brown colour, and is crowded with fine rods or fibres of felspar, besides enclosing more sparingly minute granules of magnetite, partly ranged in lines. As is usual in andesitic rocks, the final residual magma was notably more acid, and in particular of more felspathic composition, than the initial magma. Here, as in the Papadil rocks, it has oozed into vesicular cavities, and a thin slice shows little round areas occupied by material like the interstitial base already noticed. Where the rock has no glassy base, the brown glass may be absent also from the infilled vesicles, which then consist essentially of a felted mass of slender felspars, either mere fibres or skeletal shapes. The vesicles are usually not more than $\frac{1}{10}$ inch in diameter. The larger of them have not been completely occupied by the oozing in of the residual magma; and the central part is then filled by various secondary products, sometimes chalcedonic silica, sometimes a radiating fibrous carbonate which is probably aragonite.

The *glassy selvages* of these sheets remain to be described. The evidently vitreous crust is usually not more than $\frac{1}{10}$ inch thick. It is black, or has sometimes a bluish cast, and the surface shows a certain rude perlitic structure which is frequently to be seen on other tachylytes.* The presence or absence of the glassy selvage, and its varying thickness, seem to be related to the nature of the country-rock, and more particularly to the thermal conductivity of that rock. The tachylyte is better developed where the sheet traverses a dolerite sill than where it is in contact with the basalt lavas. Possibly the Papadil sheets might also have glassy edges, had they been intruded in a rock of higher conductivity than that possessed by sandstone. In hand-specimens of the Kildonan rocks the black glassy selvage seems to be rather sharply marked off from the dolerite; but in thin slices a certain transition is apparent, marked by an increasing proportion of glassy base towards the contact-surface.

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* *Tertiary Igneous Rocks of Skye*, p. 336 (1904).

The transitional band presents a very beautiful micro-structure. It shows a dense aggregate of exceedingly delicate felspar-fibres with a residuum of brown glass, the proportions of the two varying according to the distance from the actual edge of the sheet. The fibres have a plumose or sheaf-like arrangement, and they are grouped about larger felspar-elements in the form of skeleton microlites with forked and brush-like terminations (Pl. VIII., fig. 2). Very minute octahedra of magnetite occur, sometimes rather abundantly, but augite is not certainly detected.

With increase in the amount of the residual glass the felspar-fibres disappear, and the forked microlites become fewer. The actual edge of the sheet is wholly vitreous, but sometimes has in a thin slice a finely-mottled appearance, due to some secondary change. Little patches of unaltered glass, with a strong brown colour, are mingled with clear yellow-brown parts, which depolarise between crossed nicols. Close to the contact-surface there is a pronounced flow-structure.

(iii.) LATE PERIDOTITE DYKES.

Certain dykes which intersect the Torridonian sandstone in the *south of Rum* are of interest as being not basic but ultrabasic in composition. One is seen to the north of Loch Dubh an Sgòir, having a width of eight or nine feet. and running in the same direction (north 30° west) as the neighbouring basic dykes. Another, of similar width, runs for some distance in a north–south fault some 400 yards west of a smaller tarn (Loch nam Meirlach) and about half a mile south-east of Loch Papadil. Both dykes make salient features, and are noticeable by their dark colour and rough weathered surface. The most conspicuous element is olivine, in crystals a quarter to half an inch long, more or less blackened by secondary magnetite segregated along cracks. These are rather crowded together, with angular interspaces, the composition of which varies to some extent, the rock changing character rather abruptly within short distances. Ophitic augite is evident in places, while in other parts irregular little patches of white felspar are conspicuous. Thin slices [10,997–10,999] show, in addition to the minerals mentioned, rather abundant opaque octahedra of chromite (?) and sometimes flakes and patches of brown mica. The felspar plates or patches enclose rounded grains of olivine, much smaller than the large crystals. Smaller felspars of elongated rectangular section are enclosed in the ophitic plates of augite. The extinction-angles indicate anorthite. The augite is light brown, with a varying depth of tint, and between crossed nicols it sometimes shows a strong hour-glass structure. It is very noticeable that the olivine never contains the well-known inclusions of dendritic magnetite, nor is any "schiller" structure found in the augite. These negative characters, and still more the strong tendency to porphyritic development of the olivine, serve to separate these rocks petrographically from the plutonic peridotites, which in many other points they resemble. They are not quite so fresh as the plutonic varieties. A hand-specimen gave the specific gravity 3·063.

Similar ultrabasic rocks of hypabyssal types, mostly occurring as dykes, have been described in Skye; and it is there demonstrated that they are the latest of all the intrusive rocks of the Cuillins, the plutonic peridotites being the earliest.* It is reasonable to suppose that these scanty representatives in the south of Rum hold a like relative place in the Tertiary igneous sequence. In confirmation of this we find that the two dykes described both intersect sheets of basic rock belonging to the group which we have attached to the augite-andesites and probably of very late age (Papadil type, p. 164). We have no direct evidence of the relative age of these late peridotites and the pitchstones to be described in the following chapter. Since, however, there seems to be a close connection in the British Tertiary region between the augite-andesites and the pitchstones, it is very possible that these ultrabasic dykes are younger than the pitchstones, and so represent the very latest igneous intrusions in our country.

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* *Tertiary Igneous Rocks of Skye*, chap. xxii. (1904).

CHAPTER XIV.

PITCHSTONES (WITH ASSOCIATED FELSITIC ROCKS) (EIGG AND RUM).

(i.) SGÙRR OF EIGG AND OIGH-SGEIR.

The occurrences of pitchstone in the Small Isles are few; but one of them presents the largest mass of this rock in the British Isles, and possesses several points of interest. This mass, constituting the highest ground in the Isle of Eigg, will be first described, and then the other examples, which form only small dykes. The rocks represent some of the very latest intrusions of the British Tertiary succession. With the pitchstones we shall include certain felsitic rocks which are intimately associated with them, and some of which are believed to be devitrified pitchstones.

The *pitchstone of the Sgùrr of Eigg* makes an abrupt ridge, running with a curved course in a general N.W.–S.E. direction. (See map, fig. 48.) To the north-west it is cut off by the sea at Bidein Boidheach, while at the opposite end it terminates suddenly at its highest point, the Sgùrr proper (1289 feet). The breadth of the ridge varies up to about 500 yards, exclusive of some arm-like prolongations on the north-east side, which make Beinn Tighe and Corn-bheinn; but the bold escarpment which bounds the pitchstone in most places shows that it is only the relic of a more extensive body. Its shape is that of an irregular sheet with sharply undulating lower surface, and its maximum thickness is about 400 feet. The pitchstone truncates obliquely (fig. 49) the basalts and dolerite sills into which it has been intruded,* this relation being well exhibited at the precipitous easterly base of the Sgùrr, where the surface of junction dips south at about 40°. (See Frontispiece.)

The pitchstone itself seems to be a single sheet from top to bottom, but intruded in it are a number of smaller sheets of felsite, from a few feet to 30 or 40 feet in thickness (Pl. V.).

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* Sir Archibald Geikie has given a totally different interpretation of the relations of these rocks (*Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 303–309 (1871)). In his view the pitchstone is a subaërial lava-flow occupying a valley eroded in the basalt group. The survey of the ground has led to the conclusion that the rock is in reality an intrusive sheet. It is not necessary to give the full evidence here, since it has been set forth by the present writer in another place (*Quart. Journ. Geol. Soc.*, vol. lxii., pp. 40–67, pls. ii., iii. (1906)).

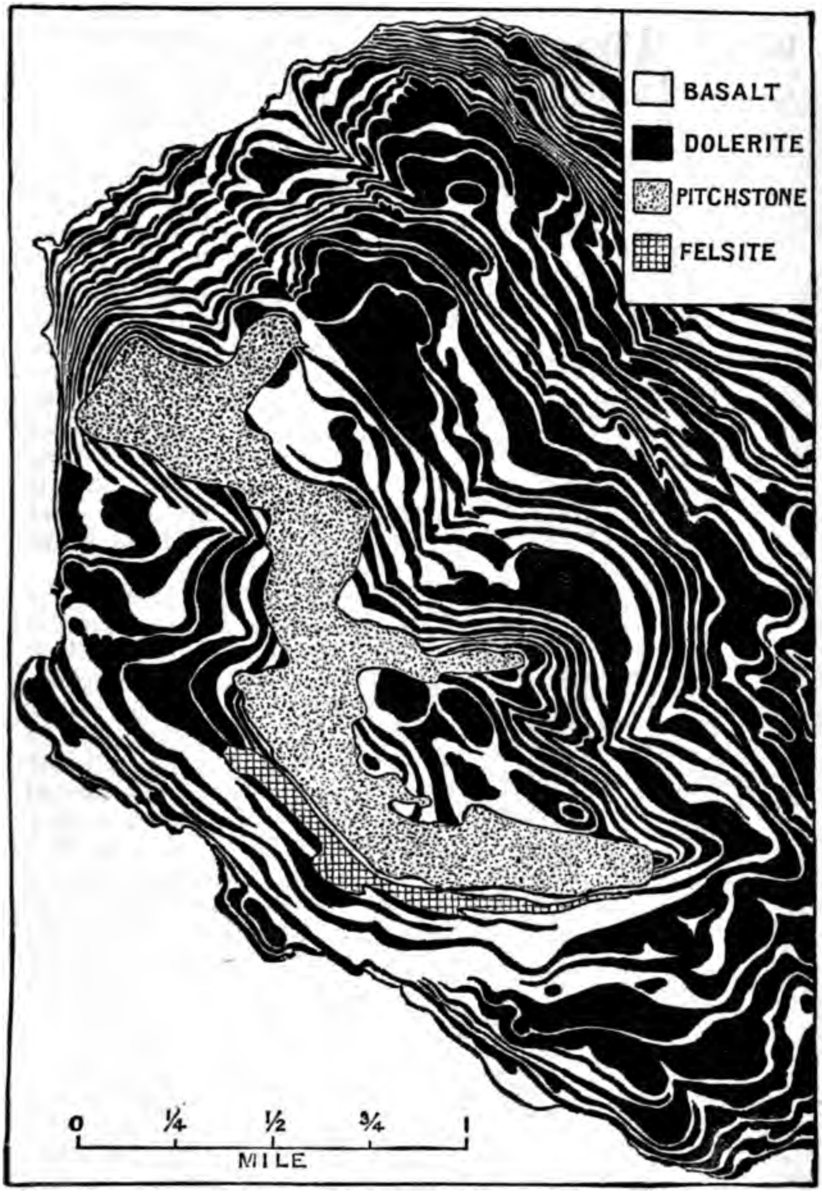


Fig. 48.—Sketch-map of the south-western part of Eigg. Scale, two inches to a mile. The map shows the alternations of basalt lavas and dolerite sills truncated obliquely by the overlying pitchstone mass of the Sgùrr, and broken through by the dyke-like intrusion of the Grulin felsite.

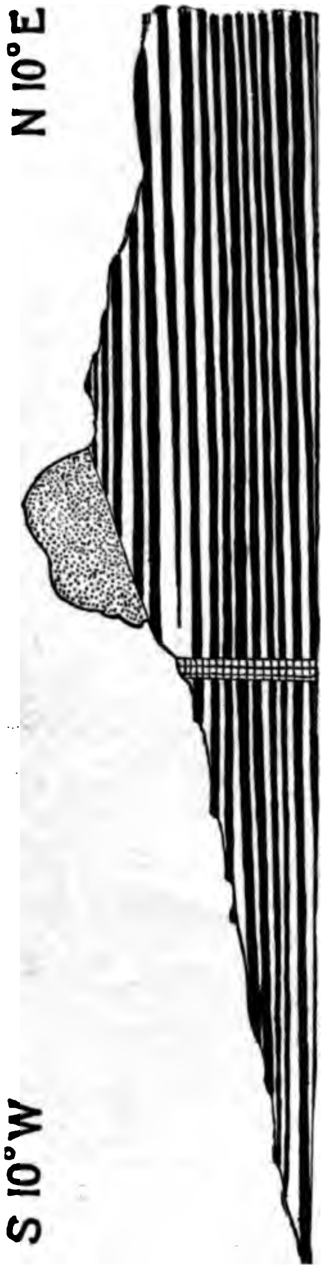
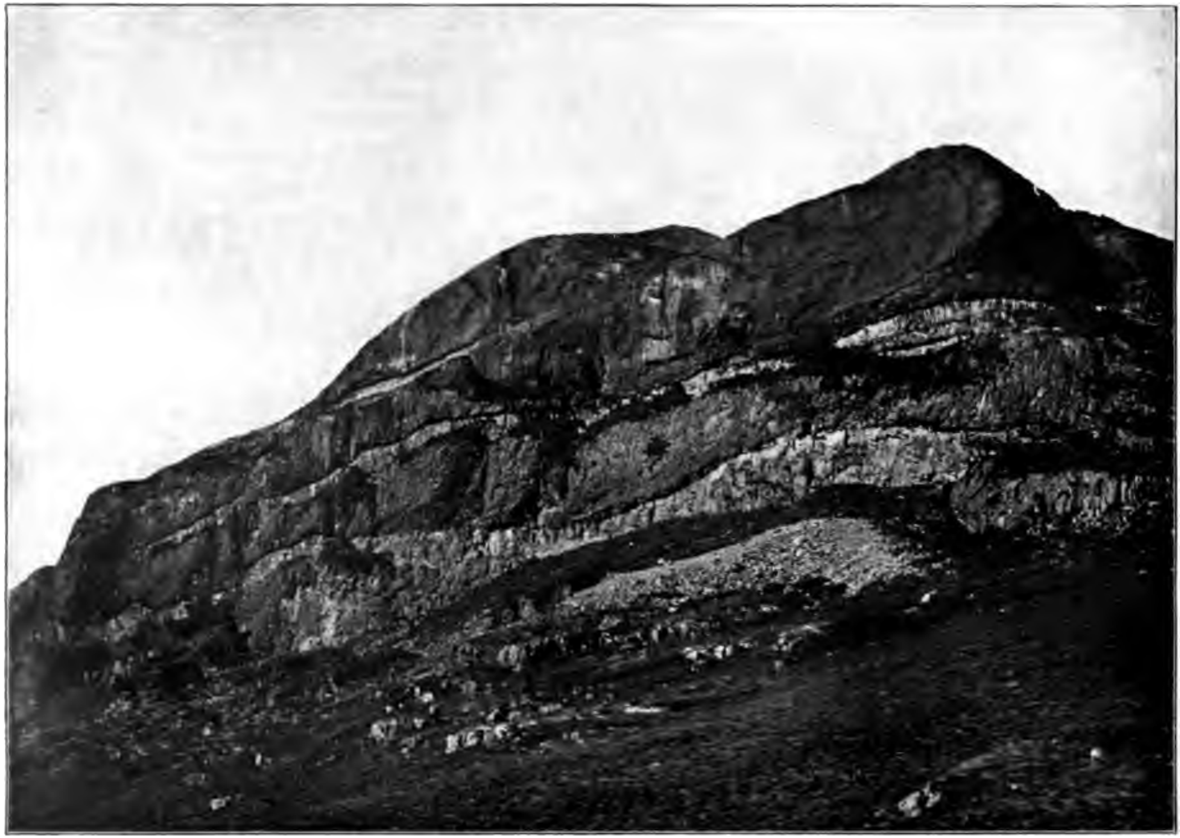


FIG. 49.—Section through the Sgùrr of Eigg, near the summit. Scale, six inches to a mile. Explanation as in the preceding figure. The lower surface of the pitchstone is shown diagrammatically as an inclined plane, omitting the minor undulations.

These are evidently very closely bound up with the pitchstone, for, while in general they cut it sharply, in some places they graduate insensibly into it. The base of the pitchstone mass is in many places brecciated and partly decomposed, and this causes it to weather into a recess at the foot of the escarpment. This basal portion of the mass, whether fresh or altered, encloses numerous pieces of the contiguous basalts and dolerites. At the southerly base of the Sgùrr, where it was in contact with the volcanic breccia already noticed (p. 53), it has picked up from that source fossil wood and pieces of Torridonian rocks.

A striking feature of the pitchstone is the beautiful *columnar structure* which characterises it throughout (Pl. VI.). In some places, *e.g.*, near the highest part of the ridge, the columns do not depart much from the vertical posture, but elsewhere they exhibit much variety in their arrangement, being frequently disposed in a radiate fashion. The columns cut across the flow-structure, which is very noticeable in most parts of the pitchstone mass. In the escarpment of the ridge the columns constantly lean inward, the pitchstone having been cut back until this relatively stable arrangement was arrived at, and the form of the ridge in ground-plan is determined simply by this consideration, the existing mass being the relic of a more extensive sheet.

PLATE V.



Part of the southern face of the ridge of the Sgùrr of Eigg. From a photograph by Mr. A. S. Reid.

The pitchstone is a *conspicuously porphyritic* rock showing abundant crystals of fresh felspar in a black velvety-looking ground. This has a lower degree of lustre than most of the pitchstones of Arran, &c., owing to the fact that it is less exclusively vitreous in composition. The basal portion of the mass, however, is more perfectly glassy, and has, when fresh, the appearance of obsidian. An analysis of the ordinary pitchstone of the Sgùrr, quoted from one of Professor Judd's papers, is given in Column I. It shows that the rock belongs to the subacid, as distinguished from the truly acid, division of the pitchstones, and can be paralleled with some occurrences in Arran and Ardnamurchan (A and B). The composition is perhaps trachytic rather than dacitic, and this is borne out by the characters of the closely associated felsitic rocks.

	I.	II.	III.	IV.	A.	B.
SiO_2 -	65·81	63·34	68·43	58·15	66·03	66·62
Al_2O_3 -	14·01	...	...	...	12·55	14·02
Fe_2O_3 -	4·43	...	...	...	2·75	5·73
FeO -	not det.	...	...	...	not det.	not det.
MgO -	0·89	...	...	...	2·33	0·33
CaO -	2·01	...	...	...	2·80	2·74
Na_2O -	4·15	4·56	4·76	4·57	5·02	6·93
K_2O -	6·08	4·50	6·31	4·85	4·13	1·51
Ignition -	2·70	...	...	...	4·20	2·83
	100·08				99·81	100·71

I.—Pitchstone ("glassy andesite") of Sgùrr of Eigg: anal. Barker North, *cit.* Judd, *Quart. Journ. Geol. Soc.*, vol. xlvi., p. 379 (1890).

II. [11,711].—Pitchstone, An Cruachan, Sgùrr of Eigg: this and the two following partial analyses by W. Pollard.

III. [11,735].—Felsite (trachyte) sheet at base of pitchstone, east end of Sgùrr of Eigg.

IV. [11,736].—Felsite (orthophyre) dyke-like intrusive mass, Grulin, south-east of Sgùrr of Eigg.

A.—Pitchstone (probably the north-south dyke), Tormore, Arran: anal. M. Tait, *cit.* Bryce, *Geology of Arran and Clydesdale*, 3rd. ed., p. 185 (1865).

B.—Pitchstone ("glassy andesite"), west side of Beinn Hiant, Ardnamurchan: anal. T. H. Holland, *cit.* Judd, *Quart. Journ. Geol. Soc.*, vol. xlvi., p. 379 (1890).

Thin slices show that the porphyritic felspars are often honeycombed with inclusions of the glassy base (fig. 50). They embrace both striated and unstriated varieties, closely associated and intergrown, giving microperthitic and cryptoperthitic structures. The ferro-magnesian silicates, which occur more sparingly, are augite and enstatite,* and the remaining minerals are magnetite and apatite. The ground-mass, in the prevalent type of the rock, is a brown glass crowded with little felspar microlites and containing also scattered minute granules of pyroxene and magnetite (Pl. IX., fig. 1, A). In the obsidian-like variety these crystallitic elements are absent.

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* The occurrence of a rhombic pyroxene does not seen to have been noticed before. Prof. Judd pointed out that the porphyritic felspars are not purely orthoclastic. (*Quart. Journ. Geol. Soc.*, vol. xlvi., p. 380 (1890)).

Specimens of the normal pitchstone from different parts of the mass show no noteworthy differences, though the size and relative abundance of the porphyritic felspars are not always constant. Three specific gravity determinations gave 2·42, 2·49, 2·496, this variation being probably related to the varying proportions of crystallitic and vitreous matter in the ground-mass. The different figures for silica and potash in Columns I. and II. probably point to a certain real variation in bulk composition in different parts of the pitchstone mass.

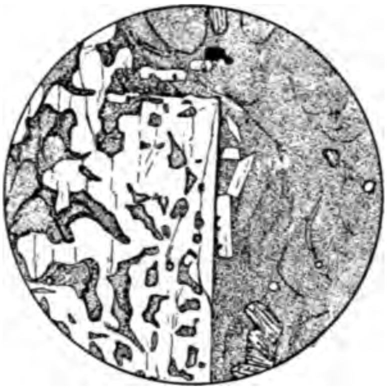

Fig. 50 [11,713].—Porphyritic Pitchstone of Sgùrr of Eigg, from base of sheet, 1000 yards west by north of summit; × 20. The large felspar crystal is honeycombed with inclusions of the ground-mass. There are smaller crystals of felspar, augite, magnetite, and apatite, and the ground-mass is here a brown glass free from crystallites.

The *subsidiary sheets of felsitic rock* are of rather inconstant and irregular behaviour; usually inclined at no great angle to the horizontal, and assuming a gently undulating form; sometimes rising more steeply, or exceptionally taking on the quasi-vertical attitude of a dyke. They have a ruder cross-jointing instead of the regular columnar structure, and their less durable nature, as compared with the pitchstone, causes them to weather into recesses (Pl. V.). The rock,. when fresh, is of a rather light-grey colour, very fine-textured, but enclosing porphyritic felspars, a quarter to half an inch long, like those in the pitchstone. It has the characters of a trachyte, and, as Dr. Pollard's partial analysis shows (III.), is richer in silica and potash than the pitchstone. In a thin slice [11,735] the large felspars are seen to be identical in characters with those in the pitchstone itself, and there are also a few octahedra of magnetite and little decomposed crystals of pyroxene. The general mass consists essentially of very small felspar rods. Interstitial quartz is not detected, though its presence seems to be indicated by the silica-percentage of the rock.

Another rock, which may be noticed in this place as possibly related to the pitchstone of the Sgùrr, is the *Grulin felsite*. It makes an elongated intrusive mass running for a mile or more on the south-east side of the Sgùrr ridge. In its western part, above the ruined cottages of Grulin, the outcrop has a width of 100 to 200 yards, and the rock cuts abruptly through the basalt lavas and dolerite sills like a dyke. Eastward, near the highest part of the Sgùrr, which it here approaches, the felsite tapers away with a rather curved course, and may perhaps have the habit rather of an inclined sheet. The intrusion not only traverses the lavas and sills, but also cuts off at least one basic dyke which it encounters, and it must be referred to a late epoch. Its proximity to the Sgùrr suggests that this mass may possibly occupy the fissure of supply by which the pitchstone magma ascended, but no more direct evidence of such relation has been observed. The rock is somewhat less acid than the pitchstone, but agrees with it very closely as regards the percentages of soda and potash. (Compare IV. with II., p. 173.) It is a grey rock enclosing porphyritic felspars like those of the pitchstone in an evidently, though finely, crystalline ground-mass. In a slice [11,736] the crystals show the same minute perthitic intergrowths, and are honeycombed in the same manner with inclusions of the ground-mass. There are small imperfect crystals of augite; and granules of the same mineral, as well as little octahedra of magnetite, are enclosed in the porphyritic felspars. The moderately fine-grained ground-mass is essentially felspathic, being composed of short stout crystals having the appearance of orthoclase, but probably cryptoperthite (anorthoclase), as indicated by the chemical composition. Quartz is not present. The rock may therefore be described as a porphyritic orthophyre.

As doubtless related to the Sgùrr of Eigg, we notice next the small island of *Oigh-sgeir* (or Hyskeir). This was first examined geologically by the late Prof. Heddle,* who discovered that it consists entirely of a columnar pitchstone like that of Eigg. Sir Archibald Geikie† subsequently visited the island, and confirmed this result. He regards Oigh-sgeir as a relic of the same sheet of pitchstone which forms the Sgùrr (in his view a subaërial lava-flow). The island is about 19 miles distant from the abrupt truncation of the Sgùrr ridge by the coast, in a direction west 15° north, which is approximately the trend of the ridge itself. Whether such a connection originally existed or not, it can scarcely be doubted that the two pitchstones are of the same epoch and have like relations. A thin slice of the Oigh-sgeir rock [6619] shows it to be identical in character with that of the Sgùrr of Eigg. The following note is contributed by Sir Archibald Geikie:—

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* "Sketch of the Geology of the Inner Hebrides," appendix C to *A Vertebrate Fauna of Argyll and the Inner Hebrides*, by J. A. Harvie-Brown and T. E. Buckley (1892).

† *Rep. Brit. Assoc.* for 1904, pp. 652, 653. *Quart. Journ. Geol. Soc.*, vol. lii., pp. 371–373 (1896).

"Oigh-sgeir consists entirely of 'pitchstone,' precisely like that of the Sgùrr of Eigg. The surface of the island presents long low parallel swells, running in a general direction 20°–45° west of north, generally of bare rock but on the higher parts of two or three ridges covered with short grass, which makes good pasturage for a few sheep. The rock is everywhere columnar, the columns irregularly polygonal, varying in size from three to ten inches in diameter, and packed so close that the domes of rock look like rounded masses of honeycomb. In some of the ridges the columns diverge radially from the surface, indicating that, though the rock has no doubt been much glaciated, the ridges, as in the Sgùrr, are in large part original contours. It is only in a few places, however, that the columns can be seen in vertical section, the best examples being along the face of the low cliff (15–20 feet) at the north-west promontory, where the slightly wavy confluent starch-like forms may be observed. As a rule, the rounded slopes of the ridges slip under the waves, which thus wash over the tesselated ends of the columns.

"The rock possesses a tolerably uniform texture throughout, though here and there it is more resinous and less fully charged with porphyritic crystals. Elsewhere devitrification has advanced further, the vitreous aspect diminishes, and there is a greater abundance of disseminated crystals. Large striated felspars are in places conspicuous.

"There is no trace of any such conglomerate as underlies the Sgùrr, nor is there any room for such on Oigh-sgeir, though it may not impossibly exist at some depth under the sea. The island represents merely the upper part of the pitchstone sheet, the main mass of which is under water. There does not appear to be any rock *in situ* but the pitchstone. A. G."

(ii.) PITCHSTONE DYKES OF EIGG AND RUM.

The pitchstone dykes of the Small Isles are few in number, and are confined to Eigg and Rum. We shall note the principal occurrences severally, before giving an account of their petrographical characters. The pitchstone already mentioned as exposed by the roadside above Cleadale will be excluded, because it has been shown to be merely an offshoot from the quartz-porphyry of Sròn Laimhrige, belonging to an earlier epoch (p. 141). It is a thoroughly acid rock, while those to be described are probably all of sub-acid composition.

At Rudh' an Tancaird, the most southerly point of *Eigg*, occur two irregular dykes or veins of pitchstone, which were first noted by Jameson, and have been described several times by later writers.* They are only a few yards apart, and intersect the basalts and dolerites with a general N.N.W.-S.S.E. direction; though their actual course is curiously irregular, with zig-zag deviations and even apparent interruptions of continuity. The western dyke varies up to about two feet in width, while the eastern one has a maximum width of three feet, but tapers to one foot seaward, and appears to die out. In each dyke the central part is dark olive-brown with a resinous lustre, and this graduates through an intermediate zone with a beautiful bluish tint into a black glassy variety on the margin. There are porphyritic felspars, less prominent than those in the rock of the Sgùrr.

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* Jameson, *Mineralogy of the Scottish Isles*, vol. ii., pp. 44, 45, and plate (1800). Macculloch, *Description of the Western Islands of Scotland*, vol. i., pp. 518, 519 (1819). Hay Cunningham, *Mem. Wern. Soc.*, vol. viii., pp. 151-153 (1839). Geikie, *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 300-303 (1871).

The eastern dyke is the more interesting There is a marked flow-structure, well shown by empty vesicles flattened parallel to the walls of the dyke; and there is a platy fracture in the same direction, especially marked near the edges. In its northern part as exposed, and also irregularly at places in the interior, this eastern dyke passes into a very compact, tough, splintery felsite. pale grey where fresh but weathering to a cream or pink colour. This is the "hornstone" of Jameson and the "porphyritic compact felspar" of Cunningham, while Macculloch likens it to chert. Macculloch regarded it as intrusive in the pitchstone, and Jameson apparently assumed the reverse relation, but there can be no doubt that the two are varieties of the same rock. In the felsitic portion of the dyke the walls show a flow-structure resembling that which Mr. Clough* has termed "rodding." It dips seaward at moderately low angles, first at 40° and 30°, and then (farther to the north) at 20° or less.

Numerous boulders of pitchstone are scattered about the shore of Eigg Harbour, and these come from a dyke at the north pier.† It has a maximum width of about 15 feet, and can be followed from the pier in a direction due north for about 100 yards, but in its northerly part it loses the vitreous character, and becomes a felsitic rock. A little farther north, and also slightly to the west of this line, a similar felsitic rock makes a small wooded escarpment facing the shore, and runs northward for about 150 yards. Although the actual relations of this are not well exhibited, it is probably connected with the pitchstone, and this supposition is confirmed by the microscopical characters of the rock. It is also noticeable that it crosses a line of fault without dislocation, and is thus referable to a late epoch. The pitchstone dyke at the pier cuts a sheet of the Kildonan type. The rock has, when fresh, a velvety black appearance, with porphyritic felspars, presenting a superficial resemblance to the pitchstone of the Sgùrr. At the edges of the dyke the lustre is more glassy, and the enclosed crystals are less numerous.

In *Rum* the most noticeable pitchstone dyke is one which intersects the granite of the west coast, and may be seen at the top of the cliff at Wreck Bay, nearly a mile south-east of the headland of A' Bhrìdeanach. It is about four feet wide, and bears nearly north–south. The rock in its freshest state is nearly black, with a vitreous lustre, and without conspicuous crystals. It is possible that other dykes are concealed under the loose *débris* which covers some parts of the granite ground or in the inaccessible parts of the sea-cliffs. One at least occurs on Sròn an t-Saighdeir; and among the older collections of the Geological Survey is a specimen labelled from Fionn-Chrò, perhaps from a dyke on that hill overlooked in our examination.

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* *Tertiary Igneous Rocks of Skye*, pp. 389-393 (1904).

† It is doubtless one which was noticed by Hay Cunningham, *Mem. Wern. Soc.*, vol. viii., p. 158 (1839).

(iii.) PETROGRAPHY OF THE PITCHSTONE DYKES.

We possess no chemical analyses of any of these pitchstone dykes, but Dr. Pollard has determined the silica-percentage of the eastern dyke at Rudh' an Tancaird as 65·55. This then is a *sub-acid*, not an acid, pitchstone, and it may probably be taken as a type of the others. The specific gravities of some of the rocks are as follows:—

Rudh' an Tancaird, west dyke, middle,	2·40
Do., east dyke, middle,	2·427
Do., do., margin,	2·391
Do., do., felsitic modification,	2·56
North pier, Eigg, middle of dyke,	2·482
Do., do., felsitic modification,	2·58
Wreck Bay, west coast of Rum,	2·39

The specific gravity of the pitchstone dykes (excluding felsitic modifications) is thus generally about 2·4, or in one case more nearly 2·5. In such rocks the specific gravity is not related in a very simple manner to the chemical composition, but depends also on the proportion of the crystalline (including crystallitic) elements to the glassy base.

The only crystals visible to the eye are felspars, which in most cases are not more than an eighth of an inch, or at most a quarter of an inch, in length. In thin slices many of these show twin-lamellation with low extinction-angles, and may be set down as oligoclase and perhaps andesine. Others, and especially the larger ones, have the general appearance of sanidine; but they often show microperthitic intergrowths of the plagioclase felspar, and between crossed nicols there is in many places a certain patchy effect which suggests that the apparently untwinned crystals are in reality cryptoperthite. These larger crystals further resemble those of the Sgùrr pitchstone in being honeycombed with inclusions of the glassy base. Almost all the slices show microporphyritic crystals of pyroxene, usually smaller than the prominent felspars. The mineral is usually augite, but in the dyke at the North Pier, Eigg, both augite and enstatite occur, in separate crystals and also in parallel intergrowth.* Little magnetite crystals and prisms of apatite are very generally present. In one slice from the North Pier dyke the iron-ore occurs in small irregular patches, which are partly translucent, with a deep brown colour, and may be identified as ilmenite.

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*The occurrence of enstatite is another point of similarity between this rock and that of the Sgùrr. It may be mentioned that enstatite is found also in some of the pitchstones of Arran.

The ground-mass of these pitchstones (excluding for the present the marginal parts of the dykes) is in general of glass enclosing very numerous minute crystallites. These are not of felspar, as in the rock of the Sgùrr of Eigg and of Oigh-sgeir, but of a ferro-magnesian silicate, as in most of the pitchstones of Arran. They are, however, too much altered for easy identification, and it is often not possible to say whether they are hornblende or pyroxene. In the Arran pitchstones, which like these contain crystals of augite, the crystallites are sometimes augite but often hornblende.

More than one type of micro-structure is represented among the pitchstone dykes of Eigg and Rum. In the rocks of Rudh' an Tancaird and Wreck Bay the crystallites, though numerous, are not densely crowded. They show a variety of stellate, sheaf-like, and comb-like groupings (Pl. IX., fig. 2), and, where they permit of optical tests, they agree with hornblende. The glassy base is partly brown, partly colourless, the two being rather sharply divided. Usually the brown part presents convex curved boundaries to the colourless; or, where the latter predominates, the brown glass occurs in irregular shreds streaked out in the direction of flow. Under high magnification the brown glass has a turbid appearance, as if it were crowded with excessively minute globulites. The crystallites within the brown areas are surrounded by clear colourless borders. In the dyke of Wreck Bay there are very numerous little spherulites, $\frac{1}{100}$ inch or less in diameter, scattered through the glassy ground. They are of irregular outline, but sharply defined, and have a light-brown colour, deepening slightly towards the centre. They are made by radiating tufts of excessively fine felspar fibres, and between crossed nicols they show an imperfect black cross. Similar growths border the felspar crystals. The ferro-magnesian crystallites, in the form of slender rods and comb-like fringes, occur only in the glassy interspaces, not in the spherulites. In the marginal parts of the dykes crystallites are only sparingly present, and of very minute dimensions: they still tend to stellate and other groupings (Pl. IX., fig. 2). The glass here is of a pale-yellow tint in thin slices, showing a very evident flow-structure and more or less marked perlitic fissures.*

The dykes at the North Pier of Eigg and on Sròn an t-Saighdeir in Rum belong to a somewhat different type. Here the glass is in general colourless, and is crowded with rod-like crystallites. The largest of these are $\frac{1}{100}$ to $\frac{1}{50}$ inch long, and smaller ones have grown perpendicularly upon these, giving something of the effect of a grating (Pl. IX., fig. 1, B). These are of a ferro-magnesian silicate. Sometimes there are also, in smaller number, slender rods and skeletons of felspar and occasional minute crystals of magnetite. Where the felspar occurs, it is not uniformly distributed, but there are little ill-defined patches free from it, and these have a brownish tint in the slice. Again, there may be little brown spherulitic patches, contrasting with the colourless glass, but enclosing the same ferro-magnesian crystallites. These patches, giving an imperfect black cross between crossed nicols, consist essentially of very slender felspar fibres with a radiate arrangement, though the brown colour is presumably due to a certain amount of interstitial glass [3302, North Pier]. In another case the brown patches are larger, and tend to run into irregular parallel streaks, which are free from ferro-magnesian crystallites. Some of these patches are sensibly isotropic; while others give a rude black cross, but show only a finely granular structure, without visible fibres [3294, Sròn an t-Saighdeir]. In their marginal parts the dykes of this type have a ground-mass of brown glass free from crystallitic growths. Flow-structure is marked, and there may be well-developed perlitic fissures [3297].

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* The perlitic pitchstone figured in Teall's "British Petrography," pl. xxxiv., fig. 5, is from one of the Rudh' an Tancaird dykes, not from the Sgùrr of Eigg as stated (p. 347).

The specimens from Fionn-Chrò differ from all the others. There are no crystals of other than minute dimensions. The glass which makes up the bulk of the rock is yellow in thin slices, and is free from the usual crystallites. It encloses, however, abundant little crystals, about ·005 inch long. Most of these are felspar, often striated and with low extinction-angles. The others are of a pyroxene, which gives bright interference-tints with constantly straight extinction, and may be set down as hypersthene. The crystals, especially of felspar, are surrounded by narrow borders of a deeper brown colour [3296].

We have remarked that two of the pitchstone dykes show *felsitic modifications*, which are intimately bound up with the normal rock, and are undoubtedly products of the same intruded magma. This is clearly seen in the case of the eastern dyke at Rudh' an Tancaird, although the irregular boundary between the vitreous and lithoidal varieties is fairly well defined. The pale, close-textured felsite at this place encloses the same porphyritic and micro-porphyritic elements as the pitchstone itself, and has the same abundant crystallites. Instead of the glassy base, however, there is a confused aggregate of felspar, partly in slender rods, partly in small crystals of more irregular shape. It is probable from the silica-percentage that no considerable amount of quartz is present, and this mineral is not to be detected in the slices. Its presence is perhaps suggested by the hardness and toughness of the rock, which gives sparks under the hammer. The micro-structure supports the view that this finely crystalline rock had originally a glassy base like the normal pitchstone, and has suffered devitrification; but there is no decisive evidence of this, and we cannot exclude the possibility that it crystallised from the magma with the characters now seen. In either case we may infer that the pitchstone is of trachytic composition.

The other felsitic rock to be noticed occurs in the little wooded escarpment north of the North Pier, and compares with the neighbouring pitchstone dyke already described. It is a grey rock, enclosing porphyritic crystals like those in the pitchstone, but having a dull fine-textured ground-mass, often with little circular white spots, which are spherulites. Thin slices show that the ferro-magnesian crystallites have been present, but are in great measure destroyed or replaced by pseudomorphs. The general mass of the rock is beautifully spherulitic, with radiating fibres of felspar, very delicate and feathery [11,693]. Sometimes the radiate structure has a rather confused arrangement, and there are in addition more distinct spherulites (those visible on a hand-specimen) presenting sharp boundaries against an interstitial ground of finely granular structure. This granular ground-mass contains a certain amount of quartz, and there are also little irregular patches of interstitial quartz in other parts of the rock, as well as little crystals on the borders of certain small druses occupied by calcite. The spherulitic mass, which preponderates, must be essentially felspathic, and it is probable that all the quartz in the rock is of secondary origin. The question, whether this rock was originally a pitchstone, is obscured by the undoubted secondary changes which it has undergone. It is doubtful whether a spherulitic structure is ever set up by the natural devitrification of glass as a process distinctly posterior to the original consolidation; and in the present case the little crystallites of ferromagnesian silicate often share in the radiate arrangement of the spherulites. It is probable therefore that the spherulitic part of the rock at least consolidated with the present structure, though the subordinate micro-granular parts may possibly represent a devitrified glassy residue.

CHAPTER XV.

GLACIATION AND GLACIAL DEPOSITS.

Except as regards altitude above sea-level, the Small Isles must have already acquired their present form and relations before the close of Tertiary time. Their features result partly from differential movement, partly from energetic erosion, both in the main completed prior to the Glacial epoch. The system of monoclinal faulting and tilting, which characterises this area in common with the rest of the basalt-plateau country, dates here as elsewhere from a defined epoch of the phase of minor intrusions. It displaces the basic sills and the minor acid intrusions, but not the later basic sheets and the augite-andesite and pitchstone intrusions. The relative elevation of Rum in the midst of the other isles, initiated at a much earlier epoch, was probably completed at about the same time as the plateau-faulting; and subsequent crust-movements in the Inner Hebrides have affected the whole area in common. The great erosion was the work of the latter half of Tertiary time. Its magnitude is to be realised by noting the laying bare of the deeper rocks and the separation of the islands from one another. On Rum the Torridonian sandstones have been brought to light by the stripping away of all but some scanty relics of the volcanic group; and plutonic rocks, probably crystallised under a cover of some thousands of feet, now build the principal elevations. On Canna and Eigg the truncated edges of the basalts and dolerites are exposed to a thickness of many hundreds of feet, and we must suppose that the rocks which are preserved are the remains of an extensive tract, once continuous across the intervening sounds. Sir Archibald Geikie considers the pitchstone of Oigh-sgeir to have been originally continuous with that of the Sgùrr of Eigg, now divided by 18 or 19 miles of sea, with soundings of 40 to 50 fathoms. The manner in which the several islands acquired their individuality, as the joint result of differential movements and prolonged erosion, is to be followed only in a general way. The way in which erosion has been guided by the plateau system of faults is to be seen in the depression between the two elevated parts of Eigg. The depression at Tarbert on Canna seems to have a like origin, and at the stage of the "100-feet" beach the two parts of this island were distinct. Canna Harbour, however, is eroded in the fragmental volcanic accumulations, and is connected with the general absence of important sill-intrusions in this group. The peridotite mountains of Rum and the pitchstone ridge of the Sgùrr of Eigg are examples of durable rock-masses left in strong relief by the progress of erosion. It would be easy to multiply illustrations showing how the features developed in the several islands under the operation of the agents of destruction stand in relation partly to tectonic and partly to lithological characters; and we can see, somewhat more generally, how the same conditions have led to the severance of the different islands as they now exist.

The differential crust-movements and practically the whole of the erosion in this area were, as we have remarked, comprised within Tertiary times. The advent of glacial conditions found the relative altitudes and surface-features substantially the same as they are to-day. The absolute elevation relative to sea-level was, however, different. Throughout Tertiary time the foundations of the Small Isles stood higher above the sea than at the present. This is evident as regards the volcanic era, for undoubtedly terrestrial accumulations of that age now pass beneath the sea. The energetic erosion during later Tertiary times, contrasted with the feeble action under existing conditions, is equally conclusive evidence of a higher altitude of the land-surface; and it is probable that this continued in some measure into the Glacial period, which was, however, in its closing stages at least, a time of subsidence.

The evidence on the ground shows that there was a general glaciation of the Small Isles by ice from the Scottish mainland, coming roughly from E.S.E., as if from the districts of Morar, Arisaig, and Moidart. This is proved both by the directions of striæ and by the distribution of boulders of recognisable rocks. On Rum and Eigg we find also indications of a local glaciation, which succeeded the general one.

(A) RUM.

On most parts of Rum smoothed and striated rock-surfaces are of frequent occurrence; but on the principal mountains, where such indications would be of special interest, the peridotites rarely preserve any marks of this kind. Nevertheless, the general direction of movement of the ice which overflowed this island is sufficiently clear. On the flatter and more open ground, especially the Torridonian tract of the north, the striæ are directed W.N.W., with occasional deviations towards west or north-west. The bold mountain-group of the southern half of the island presented, however, an obstacle, which divided and diverted the lower layers of the ice, and the striæ along the mountain-border show accordingly varying directions. In addition there is a second set of striæ, directed outwards from the mountains, and clearly proving the existence of local glaciers at a somewhat later epoch.

Boulders of foreign rocks are, on the whole, only scantily represented on Rum. They are fairly numerous along the east coast, to heights of 600 or 700 feet, being here less than a foot in diameter and consisting of coarse mica-schist and garnetiferous gneiss. Higher up, and in the interior of the mountain-tract, they are wanting, though on the northern slopes of the mountains they occur rarely up to 1800 feet (on Barkeval). It appears that the lower layers of the ice, which carried the boulders, were diverted by the shape of the ground; while, in addition, any stray boulders which found lodgment in the mountain glens may have been swept down by the later glaciers. Although there is no direct evidence bearing on the point, it is probable that even the highest summits were covered by the foreign ice. Farther west foreign boulders are met with occasionally in Kilmory Glen, Gleann Seilisdeir, and Glen Duibhal, and even at 1750 feet or more near the summit of Beinn a' Bhàrr-shaibh. They range sometimes up to two or three feet in diameter, and one of garnetiferous gneiss in the glen a little above Kilmory measures six feet. In addition there are rocks belonging to the island itself transported westward of their outcrops. Thus blocks of peridotite and Torridon sandstone are numerous on the granitic ground about Orval and Beinn a' Bhàrr-shaibh, and there are many large boulders of peridotite in the upper part of Glen Guirdil.

Boulder-clay occurs in most of the main valleys of Rum, such as Kinloch Glen, the upper parts of Glen Harris and Kilmory Glen, Glen Guirdil, and Gleann Duibhal, and in some places it attains a considerable thickness.

As regards the later local glaciers of Rum, the striæ afford clear evidence of a radial outflow from the principal mountains down the main valleys which drain them. In some places the newer striæ cross the older. Thus Kinloch Glen, running nearly in the direction of the foreign ice-flow, preserves abundant marks pointing W.N.W., but at some points along the roadside there are also striæ directed nearly northward or N.N.E. The evidence from the distribution of local boulders seems to show that glaciers headed also in the higher part of the granite tract, about Orval. The boulders of granite which occur somewhat plentifully east of Harris can only have come down Gleann Duibhal, and it is also noteworthy that the large raised beach at Harris is made up chiefly of granite boulders. In one place only do we find a considerable moraine belonging to this later glaciation. This is in Coire nan Grunnd, below Allival and Askival, and the moraine consists of large blocks of peridotite, allivalite, and eucrite derived from those mountains. It covers the shores of the loch, and extends for nearly a mile in a N.N.E. direction, crossing the Dibidil footpath just south of the ford of Allt na h-Uamha. In a few other places, and notably in Fiadh-innis (or Sandy Corrie), small morainic mounds occur with something of a crescentic form.

(B) CANNA, SANDAY, AND OIGH-SGEIR.

On Canna and Sanday boulders of foreign rocks are of frequent occurrence. They are often very abundant at sea-level, but are also found occasionally at all altitudes. The red Torridonian sandstones are the most common,* but "Moine" gneisses and

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[illegible] They were first noticed by Macculloch, *Description of the Western Islands* [illegible] *Scotland*, vol. i., p. 467 (1819).

pegmatites are also met with, and less commonly granite (? Tertiary), gabbro, Durness limestone, coarse gneiss, quartzite, and vein-quartz. The Torridonian sandstone probably comes in great part from Rum, and the same is perhaps true of the granite and gabbro. The limestone may have a like origin, for at one place on the north coast of Sanday was observed a four-feet boulder of the Monadh Dubh crush-breccia. On the lower ground of this island there are many large blocks of the red sandstone, one on the shore having a diameter of 20 feet. Boulders of other rocks are usually smaller; but at the west end of Sanday there is an eight-feet block of gneiss veined with pegmatite.

Any continuous accumulation of boulder-clay is scarcely found on Canna and Sanday. A small patch is seen in the most easterly glen of the latter island. In some places, however, it is evident that boulder-clay near the coast has been destroyed to furnish the material of the raised beaches. The thick beach at Tarbert is of sand and gravel enclosing closely-set boulders of red sandstone, with some porphyritic dolerite (from the local sills), amygdaloidal basalt, granite, and gneiss.

Concerning Oigh-sgeir Sir Archibald Geikie has supplied the following notes:—

"Large numbers of boulders and pebbles of foreign material are strewn over the little bays, which in places are white with calcareous shell-sand. The largest boulder (gabbro) observed lies on the west shore near high-water mark, and contains about 150 cubic feet. The next in size (basalt) lies near it, and contains about 60 cubic feet. A large quantity of boulders occurs farther down the slope of the shore. As a rule, the boulders are rounded, and have evidently been subjected to prolonged attrition by the sea about their present levels. The summit of the island is capped with large rounded blocks running along the crest of the ridge. They look like a fragment of a storm-beach, probably dating from a time when the land was lower than now.

"By much the most abundant material among the blocks and boulders is red Torridon sandstone and fine conglomerate; but I observed also pieces of granulitic gneiss, grey granite, pink large-grained granite, and other granites, mica-schist, quartzite, felsite, lamprophyre, white sandstone (? Jurassic), &c.

"Though I hunted for striæ, I could find none: the surface of the rock decays too much to preserve them.—A. G."

(C) EIGG.

On Eigg the striated rock-surfaces, numerous in some parts of the island, indicate again a general westward movement of the ice, modified in some measure by the form of the ground. There is nowhere any continuous deposit of boulder-clay; but foreign erratics are met with in all parts of the island excepting on the highest ground. Various gneisses and pegmatites from the mainland are the most usual rocks, and near the east coast these are fairly frequent. Inland they are less common, but boulders of gneiss from two to four feet in diameter still occur at a number of places. More rarely boulders of red Torridon sandstone have been noted. The source of these, both on Eigg and on Muck, is rather problematical, for Torridonian strata do not occur in Scotland at any place eastward of the Small Isles. No foreign boulders are found in the lee of the Sgùrr ridge, though they occur occasionally on the lower part of the ridge itself.*

Despite the small extent and moderate elevation of the high ground on Eigg, it appears that small local glaciers were not entirely wanting after the disappearance of the Scottish ice-sheet. To the south of the Sgùrr, opposite to the most noticeable gap in the rampart of columnar pitchstone, a moraine consisting of a succession of irregular mounds streams down towards the sea. It passes the Grulin shepherd's hut and reaches the coast, here about 700 yards from the ridge of the Sgùrr. It is composed essentially of pitchstone *débris*; and, scattered over and beside it, are many large blocks of pitchstone, some of the dimensions of a cottage. The smaller blocks come from the breaking up of the rock determined by the columnar jointing, and detached columns have sometimes a considerable length.† The form and arrangement of the whole accumulation would accord with the left lateral moraine of a glacier heading in the recesses of the Sgùrr, but no corresponding deposit is to be made out westward, which might mark the position of the right wing.

Blocks and smaller *débris* of pitchstone are found for a short distance on the north side of the Sgùrr, and even on the Gualainn or shoulder to the east. They extend in places beyond the limits of falling and rolling under existing conditions, and the material has perhaps reached such situations by sliding down snow-slopes. —A. H.

The following notes on the Glacial geology of the northern part of Eigg have been supplied by Mr. Barrow:—

"*Pre-Glacial Sands and Gravel near Laig Farm.*—To the south-east of Laig Bay, in the neighbourhood of Laig Farm, there is a fairly large low-lying area mainly composed of superficial material. Close to the shore the actual surface is Blown Sand, and farther inland recent Alluvium, but immediately underlying these, and appearing occasionally at the surface, is a rather widespread deposit of gravel, partly mixed with and partly merging into fine sand, both of which are largely derived from the destruction of the igneous rocks. The material of which they are composed was clearly brought down by the two streams which drain the high ground to the south and east. The more sandy portion of the deposit, however, is not confined to the area now above sea-level; soundings taken when selecting the site for the telegraph cable show that it extends far out to sea, and that no rock ribs or ledges project up through it. This latter fact is of importance, for such rock-patches occur everywhere else along this coast, and their absence here is clearly due to the presence of an old valley, now filled with sand. This valley must have been eroded when the land stood considerably higher above sea-level than at present; and its presence is of interest as an addition to the mass of evidence as to repeated movements, or periods of emergence and subsidence of the land, which have taken place within comparatively recent geological times over the whole of the British Isles. The pre-Glacial age of most of the deposit is clear, and becomes more so when the shape of the ground formed by it is studied. Close to the sea it rises to a ridge, which is succeeded inland by a silt-covered hollow, marking the position of an old lake. This lake owed its origin to ice-action, the sheet which crossed the broad hollow in the middle of Eigg having a sudden fall where it first impinged on this mass of sand and gravel. It was in consequence able to excavate the loose material to form the hollow, and to heap it up farther to the west to form the ridge near the shore already referred to. In this way a lake was formed when the ice finally melted. It is thus evident that, while this deposit is essentially of pre-Glacial age, it is partly Glacial and post-Glacial, in that part of it has been heaped up and redistributed, the curious mingling of finer and coarser material being thus accounted for..

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* An erratic of gneiss four and a half feet long was recorded by Mr. N. Macpherson at 890 feet above sea-level; *Pro. Roy. Soc. Edin.*, vol. xii., p. 212 (1883). The occasional occurrence of Torridon sandstone was also noted.

† Such columns have been carried away for use as gate-posts, *e.g.*, at the western entrance to the grounds of the lodge. A column, now prone in the heather, by the roadside north of the church, may perhaps have served some monumental purpose. The rough pillar ("Cross" on six-inch map) which stands near the schoolhouse is from a dyke of porphyritic basalt in the immediate neighbourhood, probably the same dyke which runs out to sea at the headland near Kildonan (p. 155).

"*Glacial Deposits.*—Glacial deposits composed of material foreign to Eigg are but feebly represented in the northern part of Eigg, and no true Boulder Clay has actually been observed. Fragments of foreign rocks are, however, not uncommon on the northern plateau, and these usually occur in trains, or arranged in lines, and consist of fragments of Moine-gneiss and pegmatite (coarse, granitic material which occurs as intrusive veins in the gneiss). The pegmatite is more abundant and in larger blocks. That these blocks are derived from the mainland is obvious; but their mode of occurrence also make it clear that they were picked up from the crests of the highest hills by the higher layers of otherwise perfectly clean ice. On the highest part of the northern plateau no foreign blocks were actually found; nevertheless, a few must have been carried across almost the highest point of the watershed, because several have been found in the hamlet of Cleadale, at the west foot of the table-land escarpment. One of these weighs nearly a ton, and is a typical Muscovite-pegmatite of the Muscovite-biotite-gneiss-magma. While on the table-land and the west side of the island these erratics are comparatively few in number, and often at considerable distances apart, on the seashore at the north-east of Eigg they are abundant and of more variable composition. This suggests that there may have been a considerable mass of boulder-clay heaped up against this side of the island, the sea having, however, since removed all the clay, while leaving the more durable boulders. There may have been some boulder-clay on top of the undercliff, but the great landslips would almost bury most of it. It was intended to revisit this part of the island to investigate this point and examine further the beach-boulders, but no opportunity occurred.

"*Local Drift.*—Attention has already been directed to the fact that part of the gravel and sand of Laig Farm has been somewhat re-assorted by the ice-sheet; and there can be little doubt that much of the tumbled igneous material at the foot of the great inland cliff of Cleadale has also been moved to some extent. Obviously, there must have been great pre-Glacial landslips, just as there are modern ones, and the fallen material would easily be pushed forward and heaped up, so as crudely to resemble morainic material, as the loose volcanic material at this locality occasionally does. It is not unlikely that a considerable portion of the landslip material here was forced down by the ice crossing the crest of the great cliff; for it must be remembered that the volcanic series has a distinct dip towards Cleadale, *i.e.*, in the direction of ice-movement, and any moving mass lying on these volcanic rocks would greatly facilitate the production of huge landslips.

"*Glacial Erosion.*—On top of the northern table-land at its higher portion, the series of rude terraces or steps formed by the alternation of the harder sills and softer lavas is preserved practically intact, and not appreciably modified by glacial erosion; but, as we descend to the central valley of the island, signs of this erosion soon become well marked. First, there are small ice-rounded surfaces, and later, broad shallow furrows, crossing the natural features obliquely. Before the base of the broad valley is reached, ice-eroded surfaces become much larger, and the oblique glacial features are so well marked that they can easily be recognised from the high road, looking northward. Even here, however, they are rarely strong enough to obliterate the step-features developed by natural weathering. While mapping the ground on the north side of the valley, it was noted that large masses of rock had been slightly pushed out of their proper position; the process being again facilitated by the dip of the rocks partly coinciding with the direction in which the ice was moving.

"*Production of Lake-Basins.*—There are two small peat-filled hollows in Cleadale, which have been almost certainly dug out by the ice which succeeded in passing over the top of the high table-land. Both are small, and probably have soft sedimentary material at their base, which accounts for the locally deeper digging of the ice. The more northerly has been artificially drained, and the outlet is cut in solid rock, so that there can be little doubt that it is a small rock-basin. The similar ploughing out of the plains at Laig Farm, which led to the production of a lake of more considerable size, has already been referred to. Although this lake is now silted up, there is reason to believe that it remained a lake till within historic times, for I was informed that the Gaelic name of the projecting nose of rock at the south-west side of the old lake means 'the place where boats were moored.'—G. B."

(D) MUCK.

On the Isle of Muck glaciated rock-surfaces, indicating a movement north-westward, have been observed only at two or three places. Here, in contrast with Canna and Eigg, drift-deposits cover much of the lower ground, and the relative fertility of the island is largely attributable to this circumstance.

Foreign boulders, sometimes of noteworthy size, are generally distributed on Muck, and are especially common in the northern half of the island. They are chiefly gneisses and mica-schists of the Moine series; but with these are pegmatites, unknown granites, and some Torridonian sandstones. There are also boulders of granophyre resembling those of Skye and Rum. These are abundant at some places in the north of the island, and it is not easy to conjecture their source. The modern and raised beaches at Camas na Cairidh, on the N. coast, contain abundant boulders of this granophyre and of a white sandstone, up to three feet in diameter, besides less abundant boulders of gneiss and Torridon sandstone, with the usual profusion of local dolerites and basalts. The white sandstone is doubtless from the Oolites, and resembles that of Laig Bay in Eigg. It has probably been brought to the shore of this little inlet by floating ice. On the south coast of Muck, immediately south of the highest land in the island, is a small cove with a beach composed of boulders of which about half are of foreign rocks, chiefly gneisses with some granites, Torridon sandstones, &c.—A. H.

CHAPTER XVI.

POST-GLACIAL AND RECENT GEOLOGY.

(i.) RAISED BEACHES.

Although we have found no sign of any interglacial submergence of the Small Isles, it is clear that there was about the close of the Glacial period a general subsidence of this area, in common with a larger region, for the next episode of which we have record indicates that the land stood then about 100 feet lower than at the present day. The evidence of this depression, and of the subsequent recovery by stages, is seen in the raised beaches. It would appear probable that the subsidence took effect somewhat rapidly at the close of the Glacial period; for the existence of local glaciers at a late stage, in the Rum mountains and even on the Sgùrr of Eigg, suggests that these heights were at least not less considerable than at present.

The old raised beaches are usually of rather coarse shingle, consisting largely of travelled stones, and the material has doubtless been furnished in great part by Glacial boulder-accumulations. A thick raised beach of this kind is well exposed at Tarbert in Canna. This rises to some 70 or 80 feet above the present sea-level, while that of Coroghon, near Canna House, rises over 100 feet, both belonging presumably to the "hundred-foot" stage. The large raised beach at Harris in Rum and the smaller one at the head of Camas Mòr in Muck also rise in places above the 100-foot contour-line. Of the 40-foot stage a considerable beach has existed at the head of Loch Scresort (Rum), but has been mostly obliterated in levelling the grounds of Kinloch Castle. Other relics remain near Kilmory Lodge and at other points on the north coast of the same island. The beach at Kilmory graveyard is at about 20 feet altitude, as is also that on which the cottage at Guirdil stands. Beaches at about this level are seen also at Gallanach and Camas na Cairidh, on the N. coast of Muck; but on the coasts of Canna and Eigg the precipitous cliffs generally offer no lodgment for low-level beaches. Some of the caves in the cliffs belong to a stage when the land stood lower than at present. Such is Uamh Fhraing, the well-known cave on the south coast of Eigg, where, about the close of the sixteenth century, the whole population of the island was destroyed.*

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* The story of this massacre has been told by Sir Walter Scott, Jas. Wilson, Hugh Miller, and others.

The following more detailed notes on the old beaches of Eigg are given by Mr. Barrow:—

"Of the post-Glacial raised beaches, the best marked in the northern part of the island is the "100-foot," which can be traced more or less continuously in the Cleadale area on the west side of Eigg. As in so many other districts, this beach is shown by a terraced feature rather than by the presence of any well-marked deposit; but two places were pointed out near Cnoc na Elrig where marine shells were said to occur. The ground was under corn at the time this area was examined, and the fact could not be verified. On the north-east side of the island, near the Lochan at Rudh nan Tri Clach, there is a well-marked feature indicating the position of the 100-foot beach, but the great amount of landslip material on this side renders its investigation difficult.

"A small terrace-feature in Camas Sgiotaig, or the 'Musical-sand Bay,' is the best representative of the 50-foot beach in this part of Eigg. Though of such small size that it can scarcely be shown on a one-inch map, it is singularly well defined. No shells were found, but it would be necessary to dig open the ground along the marginal line before stating positively that none are present.

"Immediately south of Eilean Thailm, on the north coast, is a small representative of the 25-foot beach. Its upper limit is fairly well defined, but it slopes seaward in a manner suggesting that the halt in the emergence of the land was not a prolonged one. The position of the beach is, however, instructive; for, as it clearly owes its preservation to the protecting influence of Eilean Thailm, it seems highly probable that the beach once had a much greater extension, and has been washed away elsewhere, owing to the absence of any similar protection. In areas more favourable to the development and protection of the 25-foot beach it has often proved singularly persistent.—G. B."

(ii.) MODERN GEOLOGICAL PROCESSES, AND DEPOSITS NOW IN PROGRESS.

The aspect of the Small Isles as now seen indicates that, as regards geological operations, destructive and constructive, the present time is broadly one of quiescence. Although the annual rainfall is heavy, amounting to 50 or 60 inches on Eigg and probably a considerably higher figure in the hilly parts of Rum, there is little sign of active erosion. That the streams have ceased to deepen their channels is in no wise surprising, if we recall that the existing surface-relief was established at a time when the land stood considerably higher above sea-level than at present. But it is also noticeable that the general surface has suffered very little from destructive action since the disappearance of the ice. The glacial striæ, whether on igneous rocks or on Torridonian sandstone, have not been obliterated. Even weathering under atmospheric action seems to be very much in abeyance, the fresh condition of the peridotites of Rum being especially remarkable.

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(a) *Alluvium.*

The modern streams of the Small Isles are, for the most part, too short and too rapid to give rise to any important deposits in their valleys. In Rum, however, in the glens of Kilmory and Kinloch, there are some not inconsiderable patches of alluvial gravel, the material doubtless derived from the drift-accumulations.

"Alluvial deposits are fairly well represented in Eigg considering the small size of the island, though most of them are more or less peat-covered. The most extensive tract occurs in the neighbourhood of Laig Farm, and represents the final filling up of an old shallow lake. That this is almost free from peat is probably due to the fact that it has been artificially drained before the peat had time to grow to any extent. The material composing this alluvium is mostly a fine silt, but it becomes coarser at the point where the two streams which supplied the silt first enter the alluvial flat. Another fairly large patch of alluvium occurs to the north-east of the main road, towards the eastern side of the island. The alluvium is here practically covered with peat. In Cleadale there are a number of peat-covered alluvial patches, one of which is specially interesting, as here the alluvium is so obviously an infilling material. It has filled up a small well-marked lake, which occurs about the middle of the Cleadale area, and its origin has already been discussed.—G. B."

(b) *Peat.*

"Peat occurs at a number of localities on Eigg; in fact wherever the ground is sufficiently flat to be almost waterlogged. As already stated, most of the alluvial areas are peat-covered, and small patches of peat occur in shallow hollows almost at the top of the higher table-land. Where the margins of these flat areas have a low slope, the peat has often crept up the slope: a good illustration of this phenomenon occurs on top of the escarpment east-south-east of Laig Farm.—G. B."

In the other isles peat forms locally to some thickness, notably in the upper part of Glen Kinloch in Rum, and over the north-eastern part of Muck; but much of this peat is of little economic value. On Canna there is little peat of any importance, the sharp declivity of the slopes ensuring in most parts of the island a natural drainage.

(c) *Modern Beaches and Blown Sand.*

The modern beaches on the shores of the Small Isles are in some places composed of boulders, largely of travelled rocks. The material in this case is derived from the drift, either directly or more often through the medium of older beaches. Elsewhere the beaches consist of sand, which has always a local origin. In the northern part of Rum it comes, of course, from the Torridonian sandstones. On the north-west coast of Eigg, in Laig Bay and Camas Sgiotaig, is a white quartz-sand derived directly from the Estuarine sandstone of the cliffs. In the latter bay, as already noticed (p. 23), the dry sand emits a shrill sound when crushed under the foot; a peculiarity first remarked many years ago by Hugh Miller.*

In the bay at Kildonan, Eigg (Poll nam Partan), the white sand is mainly of comminuted shells; and a similar shell-sand is found at numerous other places in the Small Isles. The shells are chiefly of *Patella, Littorina,* and *Pecten.* The sand may be almost purely calcareous, as in the little bays on the north coast of Muck and at the north-west corner of Sanday; or it may have a darker colour owing to an admixture of basaltic material, as in Canna Harbour. Where the coast is low and gently sloping, this calcareous sand is blown inland to considerable distances, the wind thus performing a natural marling process. This is probably one cause of the fertility of the relatively low-lying Isle of Muck, the greenest of all the Inner Hebrides.—A. H.

Blown sand is feebly represented on Eigg, the only patch of importance occurring about the shores of Laig Bay. Even here, however, there is really far less of this material than at first appears; for, except close to the sea, the blown sand is merely a skin resting on the far older sand, mainly of pre-Glacial age, already described. The blown material is derived partly from the latter and partly from the grains of comminuted Estuarine Sandstone, which are carried southward into the bay and blown ashore when left dry on the falling of the tide. The total amount so drifted is very small compared with other parts of the Scottish coast.—G. B.

(d) *Landslips.*

It seems advisable, before concluding the account of the superficial deposits, to give a short note on the vast masses of material that have slipped or fallen from the top and face of the inland cliff (?), which makes such a great feature in the northern half of Eigg. The amount of material so fallen is prodigious, and this is due to several causes. In the first place, the surface of the basalt lavas, where they underlie the sills, are essentially greasy, this character being developed by decomposition in all basaltic rocks. Where exposed to erosion, this greasy surface tends to be more or less washed away; but where covered up, it affords an easy gliding-surface, greatly facilitating the great landslips seen all along the foot of the higher table-land. The liability to slip is greatly increased in the Cleadale area, as here the beds dip outward from the escarpment; but, as already stated, it seems likely that the amount of slipped material was greatly increased by the passage of the ice over the top of the great cliff, which would naturally produce a thrust in the direction of the dip.

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* *Cruise of the "Betsey,"* pp. 58–67 (1858). The grains are sub-angular or imperfectly rounded: see Goodchild, *Trans. Edin. Geol. Soc.*, vol. vii., pl. xi., fig. 2 (1897).

In the north-east of the island the volcanic rocks and the Great Estuarine Sandstone rest on a thick mass of shales, a position which has given rise to landslips in all parts of the British Isles; so that here there is a double cause for the falling of great masses of rock. Still the dip is here into the hill, and the total amount of *débris* on the undercliff is far less than in Cleadale. Masses of rock still continue to fall from time to time, even in summer; they begin with a patter of small fragments, followed later by a crash like thunder. A brief reference may also be made to the undercliff, or belt of ground, of varying breadth, which lies at the foot of the higher table-land in the northern part of Eigg. What is its true history? Is the inland cliff really an old marine cliff or is it a true escarpment, rising from an old, and once far more extensive, land-surface, of which now only a fragment remains? The idea of an old sea-cliff naturally suggests itself at first; but in view of the gradually accumulating mass of evidence, showing the great alterations that have been produced by erosion since Pliocene times, it is by no means impossible that this lower fringing area in Eigg may be merely the remnant of a widespread and comparatively low-lying land area. That the feature is pre-Glacial is obvious, and one could hardly expect any trace of a very old beach to have escaped destruction; but, when the ground is carefully examined, the view that this undercliff is a remnant of an old marine plain, terminated by an old cliff, seems at least doubtful.—G. B.

(iii.) POPULATION, AGRICULTURE, ETC.

The population of the Small Isles at the census of 1901 was not quite 500, distributed as follows:—

Canna, - - - -	49
Sanday, - - - -	44
Rum, - - - -	149
Eigg, - - - -	211
Muck, - - - -	42
	495

In the earlier part of the last century these islands, under the system of rural economy then prevalent in the Highlands, carried a much larger population. In 1826, however, most of the inhabitants of Rum, some 400 in number, were deported to America, and a like enforced emigration from Muck took place two years later. At the census of 1831 the population had been reduced to 1015, and causes well known and often discussed produced in the succeeding sixty years a further falling-off to 436. The general decline is scarcely yet arrested; for the small increase shown in the latest returns is due mainly to the development of the estate of Rum and the inclusion of the owner's large steam-yacht. The condition of the crofters who remain is much improved, by legislative changes and by the voluntary action of the proprietors; and it may be doubted whether, according to modern standards of living, these islands are capable of supporting a larger population than they now carry. Excepting those in the employment of the several proprietors, the inhabitants have practically no occupation but crofting. There is little systematic fishing, and little likelihood of its development, especially when we have regard to the want of any good harbour on the rocky coasts of Eigg and Muck. Moreover, the constitution of the islands affords little prospect of any mining or quarrying industry.

A relatively small part of the total area of these islands is suited to agriculture. On Canna the best parts of the farm-land, both at Tarbert and in the eastern part of the island, are situated on the "100-foot" raised beach. On Rum there is very little land under cultivation. On Eigg the arable land is chiefly about Kildonan and Laig, the latter situated on Jurassic rocks and partly on Recent marine and other deposits. Muck, as a consequence of its largely drift-covered condition and other advantages, has a somewhat larger proportion of land under the plough. There are crofter villages at Laig (Eigg) and on Sanday, and more scattered crofts on all the islands except Rum. Cattle are bred on Canna and Eigg, and the good pasturage on Muck supports a small dairy-farm. The higher ground on these isles is under sheep. Rum, outside the policies of Kinloch Castle and the few enclosures in other parts of the island, is mainly deer-forest. Although the range is limited as compared with the large forests of the mainland, the quality of the breed has been maintained by judicious introduction of new blood.*—A. H.

(iv.) ARTIFICIAL WORKS ON RUM.

A point of some interest is the manner in which the natural drainage-system of the interior of Rum has been modified by artificial works, the design being to increase the catchment-basin of Kinloch Glen at the expense of its neighbours, and thus to improve the trout-fishing there and convert the burn into a salmon-river. Works having this object were carried out in 1847 by the Marquis of Salisbury, then proprietor of the island. The scheme consisted of two parts, and involved engineering difficulties which sixty years ago must have been considered formidable. Firstly, most of the water of the Kilmory River was to be diverted to Kinloch by throwing a dam across the glen at its narrowest part and making a rock-cutting across the low watershed. Incidentally a small new loch would be created above the dam. Secondly, the drainage of the Long Loch (Loch Sgathaig on the map) was to be captured by constructing a small dam at its outlet to the south and leading the water northward to the new loch and so to the

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* Concerning the deer on Rum, and the natural history of the Small Isles in general, see Harvie-Brown and Buckley, *A Vertebrate Fauna of Argyll and the Inner Hebrides* (1892).

Kinloch Burn. For the first part of the scheme the large dam 20 feet high, and the necessary cutting were completed; but the former, though massive, was ill-designed, presenting a concave surface to the pressure. It gave way after two days, causing a great rush of water down Kilmory Glen, some effects of which are still visible. The second part of the scheme had been easily carried out, but was rendered useless by this disaster, the water from the Long Loch being diverted to Kilmory instead of to Kinloch.

Subsequently a plan was devised for bringing the water of the Long Loch directly into Kinloch Burn by a series of deep rock-cuttings in the face of the hill; but this was abandoned after most of the work had been done. It has, however, been completed by the present proprietor, Sir George Bullough. Moreover, the head-waters of the Kilmory River have also been captured for Kinloch, and this by a much easier plan than that of the great dam; the stream being tapped farther back, at a considerably higher level, and led into a tributary of the Long Loch. In this way practically all the advantage originally aimed at has been secured.

The gradual adjustment of the channel to changed conditions, both in the augmented Kinloch River and in the diminished stream of Kilmory, is not without interest to the geologist. Whether the diversion of the drainage will completely realise its object, it is perhaps too early to judge. While the volume of the Kinloch River is much increased, its flow is at the same time more regulated, both by weirs and by the fact that most of the water now passes through a lake. The scouring effect of spates is thus minimised, with the result that shoals form in the lower part of the course, and especially at the weirs.—A. H.

APPENDIX.

BIBLIOGRAPHY OF THE GEOLOGY OF THE SMALL ISLES.

1703. M. Martin. *A Description of the Western Islands of Scotland* . . . , 1703. [A second, augmented edition published in 1716, 8vo, pp. xviii+392, with map and plate: a reprint of this published at Glasgow, 1884.]

1761. Emanuel Mendez da Costa. An Account of some Productions of Nature in Scotland resembling the Giants-Causeway in Ireland. *Phil. Trans.*, Vol. LII., pp. 103, 104; pub. 1762. [Canna]

1774. Thomas Pennant. *A Tour in Scotland and Voyage to the Hebrides*, 1772; 4to, pp. viii+379, plates XLIV.; Chester, 1774.

1796. [Rev. Donald M'Lean, Minister.] *The Statistical Account of Scotland*. . . . [Small Isles, vol. xvii., pp. 272–294.]

[1797.] [E. D. Clarke.] *The Life and Remains of the Rev. Edward Daniel Clarke, LL.D., Professor of Mineralogy in the University of Cambridge.* By William Otter. 4to, pp. vi+670; London, 1824. Second edition, 2 vols., 8vo, pp. iv+500, ii+486; London, 1825. [Clarke's account of tour in 1797.]

1800. [Robert Jameson.] *Mineralogy of the Scottish Isles* . . . 2 vols., 4to, pp. xxvii+ 243, iv+289; Edinburgh, 1800.

1808. [Robert Jameson.] Mineralogical Queries, proposed by Prof. Jameson. *Mem. Wern. Soc.*, Vol. I., pp. 107-125; 1808. [Eigg.]

1814. J. MacCulloch. Miscellaneous Remarks accompanying a Catalogue of Specimens transmitted to the Society. *Trans. Geol. Soc.*, Vol. II., pp. 388-449, Plates 31-32; 1814. [Eigg, Rum.]

1819. John Macculloch. *A Description of the Western Islands of Scotland* . . . 2 vols., 8vo text and 4to atlas; pp. xv+587, vii+589, 91+xxxiii plates and ten maps; London, 1819.

1820. A. Boué. *Essai géologique sur l'Ecosse.* 8vo, pp. x+521, with seven folding plates and two maps; Paris, no date [1820].

1822. L. A. Necker de Saussure. *A Voyage to the Hebrides, or Western Isles of Scotland* . . . [included in Vol. VIII. of *New Voyages and Travels*]. 8vo, pp. ii + 116; London, 1822.

1824. John Macculloch. *The Highlands and Western Isles of Scotland . . . in letters to Sir Walter Scott, Bart.* 4 vols., 8vo; London, 1824. [Eigg, Vol. IV., pp. 93-96.]

John Macculloch. List of the Localities of some of the rarer Scottish Minerals. *Edin. Journ. Sci.*, Vol. I., pp. 225-236; 1824. [Rum.]

1829. [K.] von Oeynhausen and [H.] von Dechen. Die Insel Eigg. *Karst. Archir für Min.* Vol. I., pp. 105-114, Pl. IV.; 1829.

1831. Henry Witham. *Observations on Fossil Vegetables, accompanied by Representations of their Internal Structure, as seen through the Microscope.* 4to, pp. 48, and six plates; Edinburgh, 1831. [Eigg.]

John Lindley and William Hutton. *The Fossil Flora of Great Britain* . . . 3 vols., 8vo; London, 1831-7. [Eigg, Vol. I. (1831-3), pp. 91, 92, and Pl. 30.]

1833. H. Witham. *The Internal Structure of Fossil Vegetables found in the Carboniferous and Oolitic Deposits of Great Britain. Described and illustrated.* Edinburgh, 1833. [Eigg.]

William Nicol. Observations on the Structure of Recent and Fossil Coniferæ. *Edin. New Phil. Journ.*, Vol. XVI., pp. 137-158; 1833. [Eigg.]

1834. W. Nicol. On the Anatomical Structure of Recent and Fossil Woods. *Rep. Brit. Assoc.* for 1834, Trans. Sect., p. 660; pub. 1835.

1839. R. J. Hay Cunningham. On the Geognosy of the Isle of Eigg. *Mem. Wern. Soc.*, Vol. VIII., pp. 144-163, Pl. V.; 1839.

1840. [John MacCulloch.] *A Geological Map of Scotland by Dr. MacCulloch, F.R.S., &c.* Published by order of the Lords of the Treasury. By S. Arrowsmith, Hydrographer to the King. [Scale, ¼ inch to a mile.] 1840.

1844. James Nicol. *Guide to the Geology of Scotland* . . . , *with a geological map and plates.* 8vo, pp. 272, plates X.; Edinburgh, 1844.

1845. [Rev. Donald Maclean, Minister.] *The New Statistical Account of Scotland* . . . [Small Isles, Vol. XIV., pp. 145-154.]

1857. Hugh Miller. *The Testimony of the Rocks* . . . 8vo pp. xii + 501; Edinburgh, 1857. [Eigg, p. 469.]

1858. HUGH MILLER. *The Cruise of the "Betsey"* . . . 8vo, pp. ii+486; Edinburgh, 1858. [Edited by W. S. Symonds from articles in "The Witness." Eigg, Rum.]

JAMES NICOL. *Geological Map of Scotland* [scale, $\frac{1}{10}$ inch to a mile], with *Note Explanatory of the Geological Map of Scotland*; Edinburgh, no date [1858].

ROBERT PHILIPS GREG and WILLIAM G. LETTSOM. *Manual of the Mineralogy of Great Britain and Ireland.* 8vo, pp. xvi+483; London, 1858.

1859. HUGH MILLER. *Sketch-book of Popular Geology* . . . 8vo; Edinburgh, 1859. [Eigg and Muck, pp. 136-138.]

1861. SIR RODERICK I. MURCHISON and ARCHIBALD GEIKIE. *First Sketch of a New Geological Map of Scotland, with Explanatory Notes,* 22 8vo pp. and folding map [scale, 15 miles to an inch]; Edinburgh, 1861.

1864. A. BOUÉ. Ueber die saülenförmigen Gesteine, einige Porphyrdistricte Schottlands, so wie über die vier Basaltgruppen des nördlichen Irlands und der Hebriden. *Sitz. k. Akad. Wien* (N.S.), Vol. XLIX., pp. 439-452; 1864.

1865. ARCHIBALD GEIKIE. *The Scenery of Scotland viewed in connexion with its Physical Geology.* 8vo, pp. xv+360, with geological map; London and Cambridge, 1865. [Second ed. 1887, third ed. 1901. Eigg.]

J. F. CAMPBELL. *Frost and Fire* . . . 2 vols., 8vo; Edinburgh, 1865. [Eigg, Vol. II., p. 161.]

1867. ARCHIBALD GEIKIE. On the Tertiary Volcanic Rocks of the British Islands. *Proc. Roy. Soc. Edin.*, Vol. VI., pp. 71-75; published 1869. [Eigg.]

1868. ARCHIBALD GEIKIE. The Geological Origin of the Present Scenery of Scotland. *Journ. Trav. and Nat. Hist.*, Vol. I., pp. 1-21; 1868. [Eigg.]

1871. ARCHIBALD GEIKIE. On the Tertiary Volcanic Rocks of the British Islands. First paper. *Quart Journ. Geol. Soc.*, Vol. XXVII., pp. 279-310, Pl. XIV.; 1871. [Eigg.]

1872. S. ALLPORT. On the Microscopic Structure of the Pitchstones of Arran. *Geol. Mag.*, Vol. IX., pp. 1-10; 1872. [P. 8, Sgùrr of Eigg.]

1874. JOHN W. JUDD. The Secondary Rocks of Scotland. Second paper. On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata. *Quart. Journ. Geol. Soc.*, Vol. XXX., pp. 220-301; 1874.

1877. [Anonymous.] *Miller's Royal Tourist Guides to the Highlands and Islands: Skye, Gairloch, Eigg, and Loch Maree.* Illustrated, with map and plates. Oban: James W. Miller, 1877. [Eigg.]

1878. John W. Judd. The Secondary Rocks of Scotland. Third paper. The Strata of the Western Coasts and Islands. *Quart. Journ. Geol. Soc.*, Vol. XXXIV., pp. 660-741, Pl. XXXI.; 1878.

M. Forster Heddle. Chapters on the Mineralogy of Scotland. Chapter Fourth: Hornblende, Augite, and Serpentinous Change. *Trans. Roy. Soc. Edin.*, Vol. XXVIII., pp. 453-555; 1878. [Rum, pp. 468 478.]

1879. M. Forster Heddle. Chapters on the Mineralogy of Scotland. Chapter Sixth: Chloritic Minerals. *Trans. Roy. Soc. Edin.*, Vol. XXIX., pp. 55-118. [Rum, pp. 84-88, 102, 103.]

[David Milne Home, and others.] Fifth Report of the Boulder Committee. *Proc. Roy. Soc., Edin.*, Vol. X., pp. 113-177, Pls. I-XII.; 1879. [Canna and Sanday, pp. 132, 133.]

1880. [M. F.] Heddle. Minerals New to Britain. *Min. Mag.*, Vol. V., pp. 1-25; published 1882. [Rum.]

1882. M. Forster Heddle. Chapters on the Mineralogy of Scotland. Chapter Seventh: Ores of Manganese, Iron, Chromium, and Titanium. *Trans. Roy. Soc. Edin.*, Vol. XXX., pp. 427-466; 1882. [Rum, pp. 461, 462.]

[M. F.] Heddle. Geological Notes. . . , Leaf-bed in Canna . . . The Pitchstone-Porphyry River of the Scuir of Eigg. *Proc. Roy. Soc. Edin.*, Vol. XI., pp. 630-636; 1882.

1883. [Norman Macpherson.] Ninth Report of the Boulder Committee. *Proc. Roy. Soc. Edin.*, Vol. XII., pp. 193-218; 1883. [Eigg, pp. 212-214.]

1884. John Starkie Gardner. *A Monograph of the British Eocene Flora.* Vol. II: *Gymnospermæ. Mem. Palæontog. Soc.*, 1883-6. [Canna, pp. 85-89, and Pl. X., fig. 2.]

1885. John W. Judd. On the Tertiary and Older Peridotites of Scotland. *Quart. Journ. Geol. Soc.*, Vol. XLI., pp. 354-418, Plates X.-XII.; 1885. [Rum.]

John W. Judd. On the Gabbros, Dolerites, and Basalts, of Tertiary Age, in Scotland and Ireland. *Quart. Journ. Geol. Soc.*, Vol. XLII., pp. 49-95, Plates IV.-VII.; published 1886. [Rum.]

1886-8. J. J. Harris Teall. *British Petrography* . . . Roy. 8vo, pp. viii + 469, plates XLVIII.; London, 1888. [Rum, Eigg, pp. 88, 89, 347, Pl. V., fig. 1, and Pl. XXXIV., fig. 5.]

1887. J. STARKIE GARDNER. On the Leaf-beds and Gravels of Ardtun, Carsaig, &c., in Mull. *Quart. Journ. Geol. Soc.*, Vol. XLIII., pp. 270-299, Pls. XIII.-XVI.; 1887. [Canna, p. 276.]

1888. ARCHIBALD GEIKIE. The History of Volcanic Action during the Tertiary Period in the British Isles. *Trans. Roy. Soc. Edin.*, Vol. XXXV., pp. 21-184, Pls. I., II.; 1888.

CECIL CARUS-WILSON. *Musical Sand. A Paper read before the Bournemouth Society of Natural Science.* 12mo, pp. 20; Poole, 1888. [Eigg.]

1889. JOHN W. JUDD. The Tertiary Volcanoes of the Western Isles of Scotland. *Quart. Journ. Geol. Soc.*, Vol. XLV., pp. 187-218; 1889. [Rum.]

A. W. RÜCKER and T. E. THORPE. A Magnetic Survey of the British Isles for the Epoch January 1, 1886. *Phil. Trans.* (A), Vol. 181, pp. 53-328, Pls. 1-14; pub. 1890. [Canna, &c.]

1890. JOHN W. JUDD. The Propylites of the Western Isles of Scotland, and their Relation to the Andesites and Diorites of the District. *Quart. Journ. Geol. Soc.*, Vol. XLVI., pp. 341-384, Pls. XIV., XV.; 1890. [Eigg, pp. 379, 380.]

A. SCHENK. [On Fossil Wood from Sgùrr of Eigg.] Zittel's *Handbuch der Paläontologie*, Abth. II., p. 855.

1891. CECIL CARUS-WILSON. The Production of Musical Notes from Non-Musical Sands. *Nature*, Vol. XLIV., pp. 322, 323; 1891. [Eigg.]

1892. SIR ARCHIBALD GEIKIE. *Geological Map of Scotland . . . Topography by John Bartholomew* [scale, $\frac{1}{10}$ inch to a mile], with *Explanatory Notes to accompany a new Geological Map of Scotland*, pp. 23; Edinburgh, 1892.

SIR ARCHIBALD GEIKIE. [The History of Volcanic Action within the Area of the British Isles.] Anniversary Address of the President. *Quart. Journ. Geol. Soc.*, Vol. XLVIII., Proc., pp. 60-179; 1892. [Eigg, p. 168.]

M. F. HEDDLE. Sketch of the Geology of the Inner Hebrides: forming Appendix C, pp. 244-252, of *A Vertebrate Fauna of Argyll and the Inner Hebrides*, by J. A. Harvie-Brown and Thomas E. Buckley; Edinburgh, 1892. [Eigg, Oigh-sgeir.]

1894. SIR ARCHIBALD GEIKIE. On the Traces of Two Rivers belonging to Tertiary Time in the Inner Hebrides. *Rep. Brit. Assoc.* for 1894, pp. 652, 653; pub. 1895. [Oigh-sgeir, Canna, and Sanday.]

1895. A. MACIVOR. Musical Sands. *Temple Bar*, Vol. CVI., pp. 79-85; 1895. [Eigg.]

1895. John B. Pettigrew. The Island of Rum. *Scott. Mount. Club Journ.*, Vol. III., pp. 278-283; 1895.

Sir Archibald Geikie. The Latest Volcanoes of the British Isles. *Trans. Geol. Soc. Glasg.*, Vol. X., pp. 179-197; published 1896.

1896. Sir Archibald Geikie. The Tertiary Basalt-plateaux of North-Western Europe. *Quart. Journ. Geol. Soc.*, Vol. LII., pp. 331-405, Pls. XV.-XIX.; 1896. [Canna, Sanday, Oigh-sgeir.]

A. T. Metcalfe. The Tertiary Lava-Fields of the West Coast of Scotland. *Trans. Nottingham Nat. Soc.*, 12 pp.; 1896. [Eigg.]

J. G. Goodchild. Desert Conditions in Great Britain. *Trans. Edin. Geol. Soc.*, Vol. VII., pp. 203-222, Pl. XI.; pub. 1897. [Eigg, Pl. XI., fig. 2.]

H. Rosenbusch. *Mikroskopische Physiographie der Massigen Gesteine*, 3rd ed., 8vo, pp. xiv + 1360, plates VI.; Stuttgart, 1896. [Rum, pp. 312, 464, 492.]

1897. Sir Archibald Geikie. *The Ancient Volcanoes of Great Britain.* 2 vols., large 8vo, pp. xxiv + 477, viii + 492, with seven maps; London, 1897.

1898. W. W. Watts. *Geology for Beginners.* 8vo, pp. xvii + 352; London, 1898. [Muck, Eigg, Rum, and Canna, p. 295.]

1901. M. Forster Heddle. *The Mineralogy of Scotland.* Edited by J. G. Goodchild. 2 vols., roy. 8vo, pp. lviii + 148, viii + 247, with many plates; Edinburgh, 1901.

1903. J. J. H. Teall, Director. *Summary of Progress of the Geological Survey* . . . for 1902 . . . [A. Harker (Rum) and G. Barrow (Eigg), pp. 106-115.]

Alfred Harker. The Overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses. *Quart. Journ. Geol. Soc*, Vol. LIX., pp. 189-216, Pl. XIV.; 1903.

J. G. Goodchild. The Natural History of Scottish Zeolites . . . With an Appendix by James Currie. *Trans. Geol. Soc. Glasgow*, Vol. XII., Supplement, pp. xi + 68; 1903.

1904. Alfred Harker. Exhibition of Specimens of Tertiary Plutonic Rocks (including Gneisses) from the Isle of Rum. *Rep. Brit. Assoc.* for 1904, p. 561; published 1905: also *Geol. Mag.*, 1904, p. 574.

J. J. H. Teall, Director. *Summary of Progress of the Geological Survey* . . . for 1903. [W. Pollard (Rum), p. 56; A. Harker, pp. 92-95.]

1904. **James Currie.** Note on some new localities for Gyrolite and Tobermorite. *Min. Mag.*, Vol. XIV., pp. 93-95; pub. 1905. [Sanday, &c.]

1905. **Alfred Harker.** The Tertiary Crust-Movements of the Inner Hebrides. *Trans. Edin. Geol. Soc.*, Vol. VIII., pp. 44-350., Pl. X.; 1905. [Rum.]

W. Pollard. Chemical Work [analyses of six rocks from the Small Isles]. *Summary of Progress of Geol. Sur.* for 1905, pp. 73, 74; pub. 1906.

1906. **Alfred Harker.** The Geological Structure of the Sgùrr of Eigg. *Quart. Journ. Geol. Soc.*, Vol. LXII., pp. 40-67, Pls. III., IV.; 1906.

R. J. Strutt. On the Distribution of Radium in the Earth's Crust, and on the Earth's Internal Heat. *Proc. Roy. Soc* (A), Vol. LXXVII., pp. 472-485; 1906.

1907. **Alfred Harker.** Igneous Rock-Magmas as Solutions. *Sci. Progress*, vol. ii., pp. 239-254; 1907. [Rum, pp. 245, 253.]

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EXPLANATION OF PLATES VII.-IX.

PLATE VII.

FIG. 1.—Dissolution of xenolith of eucrite in the invading granite-magma, from non-banded part of gneissic group, roadside north by west of Loch Sgathaig (Long Loch), Rum [10,727]; × 30: see p. 105.

FIG. 2.—Mugearites; × 150.

A. Top of escarpment, Laig, Eigg; showing oligoclase and orthoclase, magnetite, apatite, and a brown micaceous mineral: see p. 132.

B. Top of Creag na Stairdean, Rum [10,996]; showing oligoclase, magnetite, small granules of augite, and an interstitial base, largely glassy: see p. 132.

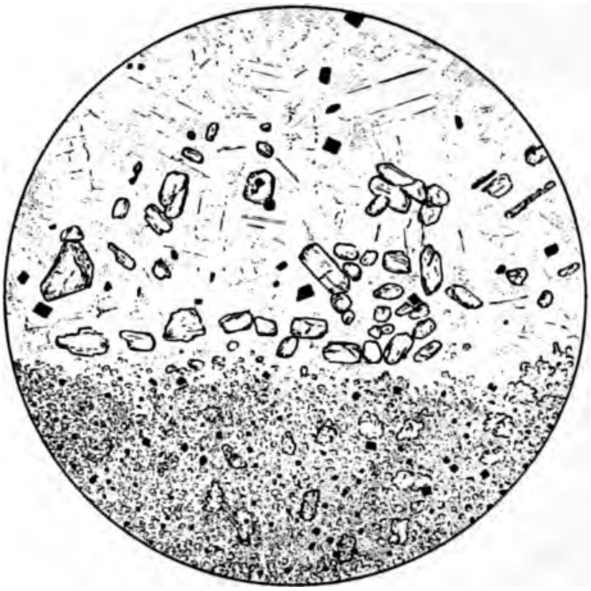

FIG. 1.

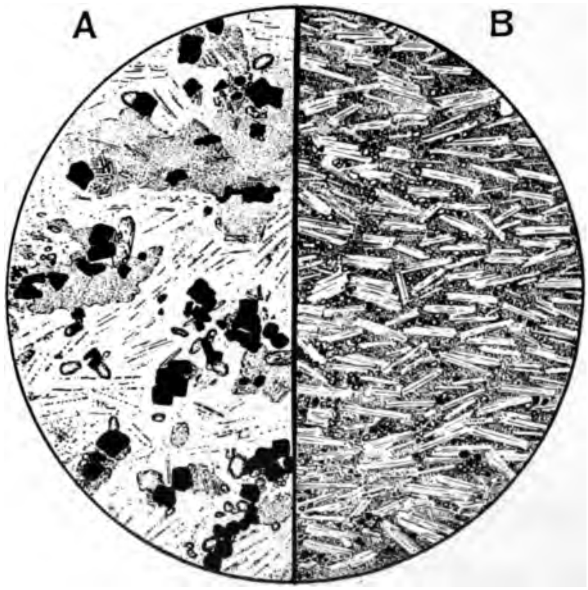

FIG. 2.

PLATE VIII.

FIG. 1.—Tachylytes of mugearitic affinities.

A. Centre of dyke at Camas na Cairidh, Muck; showing interlacing groups of rods of a decayed ferro-magnesian mineral; × 30: see p. 160.

B. Centre of dyke on island rock at Gallanach, Muck; showing grouped crystallites of magnetite; × 150: see p. 161.

FIG. 2.—Tachylyte of andesitic affinities, edge of intrusive sheet at Kildonan, Eigg; showing plumose groupings of extremely delicate felspar fibres about forked microlites: × 150: see p. 168.

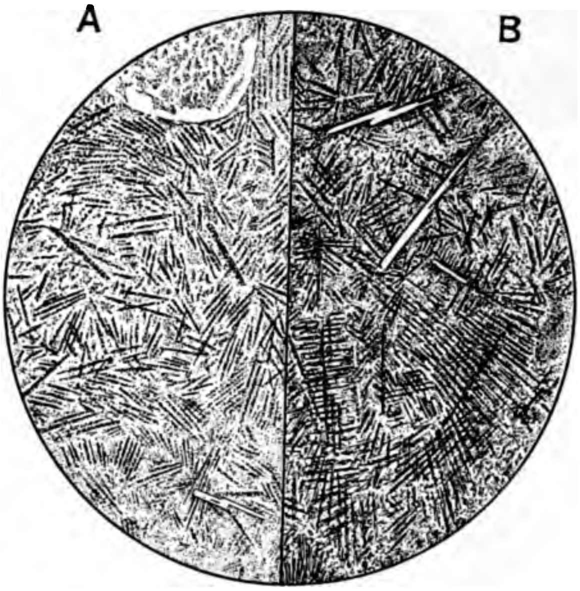

FIG. 1.

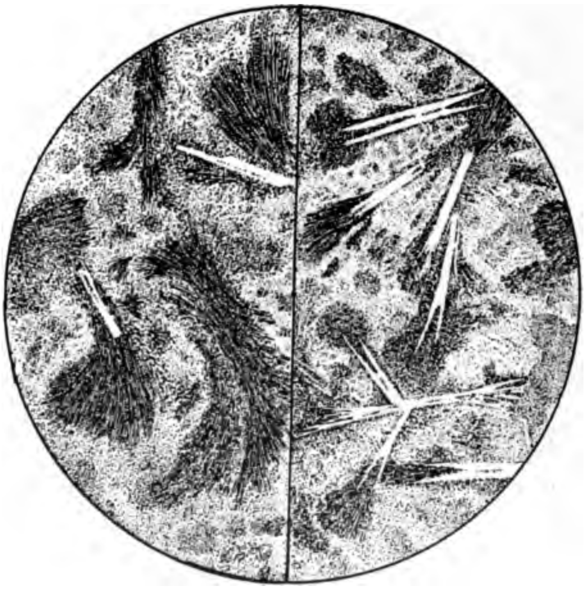

FIG. 2.

PLATE IX.

FIG. 1.—Pitchstones; × 150.

A. Sgùrr of Eigg; showing the ground-mass of brown glass with minute felspar microlites and scattered granules of pyroxene and magnetite: see p. 174.

B. Sròn an t-Saighdeir, Rum; showing grouped crystallites of a ferro-magnesian silicate in a colourless glass, and recalling in micro-structure some of the mugearitic tachylytes (*cf.* Pl. VII., fig. 1, A) [3294]: see p. 179.

FIG. 2.—Pitchstone, eastern dyke, Rudh' an Tancaird, Eigg; × 150. The larger part of the figure shows the interior of the dyke, with stellate groupings of ferro-magnesian crystallites in a mottled brown and colourless glassy base. The remaining quadrant shows the edge of the dyke, with fewer and more minute crystallites in a pale yellow glass: see p. 179.

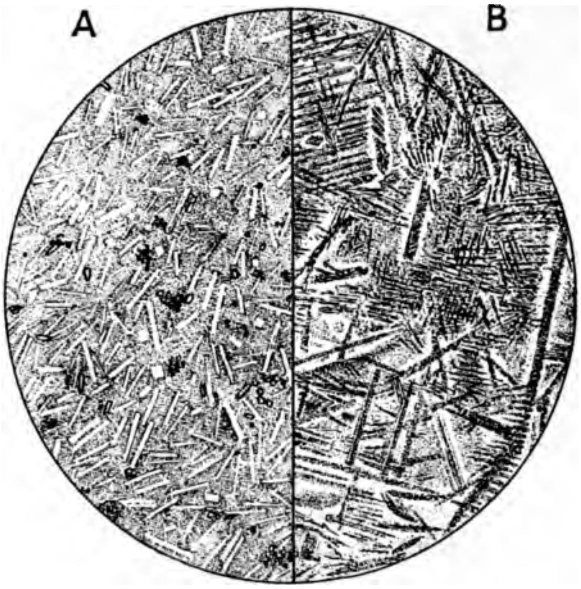

FIG. 1.

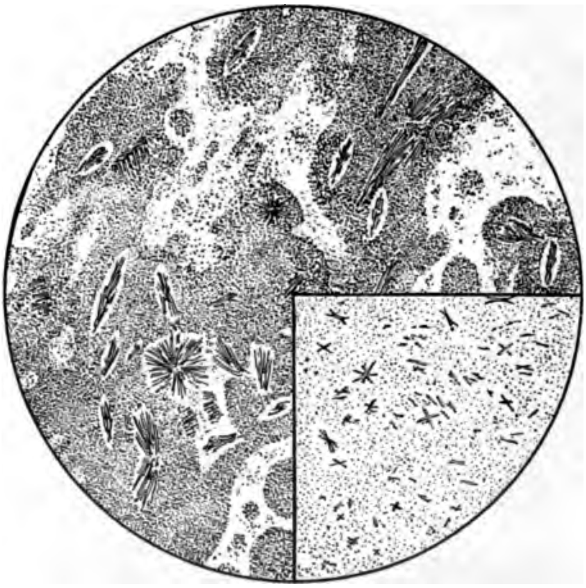

FIG. 2.

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